U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

ORDER 8260.54

Effective Date:
June 16, 2006

SUBJ: THE UNITED STATES STANDARD FOR AREA NAVIGATION (RNAV)

FOREWORD

The Global Positioning System (GPS) provides greater flexibility in the design of instrument approach procedures. FAA Order 8260.38, Civil Utilization of Global Positioning System (GPS), introduced GPS approach procedures into the National Airspace System (NAS) in 1993. Order 8260.48, Area Navigation (RNAV) Approach Construction Criteria (1999) and Order 8260.50, The United States Standard for LPV Approach Procedure Construction Criteria (2002), introduced Wide Area Augmentation System (WAAS) approach construction criteria. As the NAS evolves from one based on conventional navigation aids to an Area Navigation (RNAV) system, the capability of the GPS based systems is being more clearly quantified. This document consolidates RNAV criteria, incorporating GPS, WAAS, and Local Area Augmentation System (LAAS) navigation systems. Significant improvements have been made to WAAS criteria, based on demonstrated performance since system commissioning.

Signed by John Allen

James J. Ballough
Director, Flight Standards
Service

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Initiated By: AFS-420

RECORD OF CHANGES

8260.54

CHANGE TO BASIC	SUPPLEMENTS			OPTIONAL USE	CHANGE TO BASIC	SUPPLEMENTS			OPTIONAL USE

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CHAPTER 1. GENERAL

1.0 PURPOSE.

This document specifies criteria for obstacle clearance evaluation of area navigation (RNAV) approach procedures; e.g., Localizer Performance with Vertical Guidance (LPV), Lateral Navigation/Vertical Navigation (LNAV/VNAV), and LNAV. These criteria support RNAV transition to an instrument landing system (ILS) final approach.

NOTE: These criteria do not support VOR/DME RNAV, INS, or IRU RNAV operations.

1.1 DISTRIBUTION.

This order is distributed in Washington headquarters to the branch level in the Offices of Airport Safety and Standards and Communications, Navigation, and Surveillance Systems; Air Traffic, Airway Facilities, and Flight Standards Services; to the National Flight Procedures Group and the Regulatory Standards Division at the Mike Monroney Aeronautical Center; to branch level in the regional Flight Standards, Airway Facilities, Air Traffic, and Airports Divisions; special mailing list ZVS-827, and to Special Military and Public Addressees.

1.2 CANCELLATION.

Order 8260.50, United States Standard for Wide Area Augmentation System (WAAS) LPV Approach Procedure Construction Criteria, dated September 6, 2002.

1.3 BACKGROUND.

The National Airspace System (NAS) is evolving from a system of conventional ground based navigational aids [very high frequency omnidirectional radio range (VOR), nondirectional radio beacon (NDB), etc.] to a system based on RNAV [Global Positioning System (GPS), WAAS, local area augmentation system (LAAS), etc.] and required navigation performance (RNP). This order provides criteria for the application of obstacle clearance standards to approaches based on RNAV.

1.4 EFFECTIVE DATE. July 7, 2006.

1.5 DEFINITIONS.

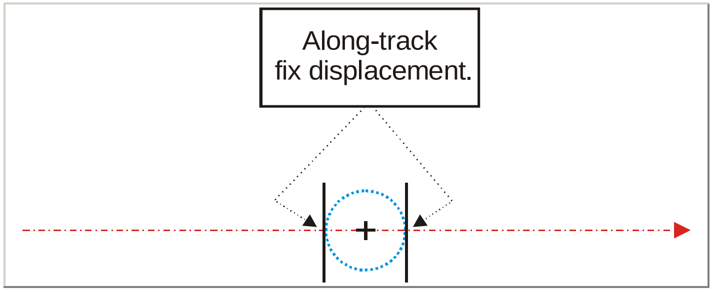
1.5.1 Along-Track Distance (ATD).

A distance specified in nautical miles (NM) along a defined track to an RNAV fix.

1.5.2 Along-Track (ATRK) Fix Displacement Tolerance (FDT).

The amount of possible longitudinal fix positioning error on a specified track expressed as a ± NM value (see figure 1-1).

Figure 1-1. ATRK FDT



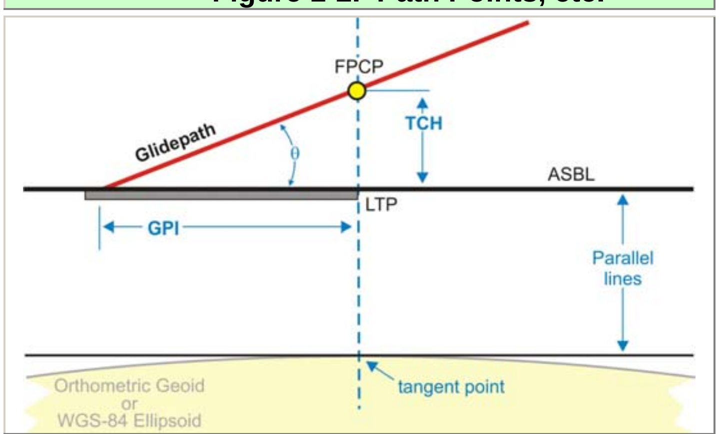
1.5.3 Approach with Vertical Guidance (APV).

There are three classifications of approach procedures: Precision Approaches (PA), Nonprecision Approaches (NPA), and an Approach with Vertical Guidance (APV). APV procedures are based on a navigation system that provides course and glidepath deviation information, but they are not required to meet the precision approach standards of the International Civil Aviation Organization (ICAO) Annex 10. Barometric vertical navigation (Baro VNAV), localizer-type directional aid (LDA) with glidepath, and **localizer performance with vertical guidance (LPV)** are examples of APV procedures.

1.5.4 Approach Surface Baseline (ASBL).

The ASBL is a horizontal line tangent to the surface of the earth at the landing threshold point (LTP) or fictitious threshold point (FTP), aligned with the final approach course (see figure 1-2).

Figure 1-2. Path Points, etc.



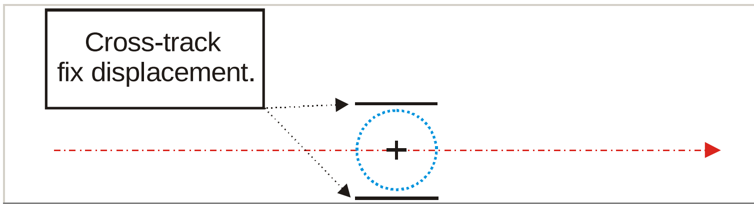
1.5.5 Barometric Altitude.

The barometric altitude measured above mean sea level (MSL) based on atmospheric pressure measured by an aneroid barometer. This is the most common method of determining aircraft altitude.

1.5.6 Cross-Track (XTRK) Fix Displacement Tolerance (FDT).

The amount of possible lateral positioning error expressed as a ± NM value (see figure 1-3).

Figure 1-3. XTRK FDT Positioning Error



1.5.7 Decision Altitude (DA).

The DA is a specified barometric altitude at which a missed approach must be initiated if the required visual references to continue the approach have not been acquired. DA is referenced to MSL. It is associated with vertically guided approach procedures.

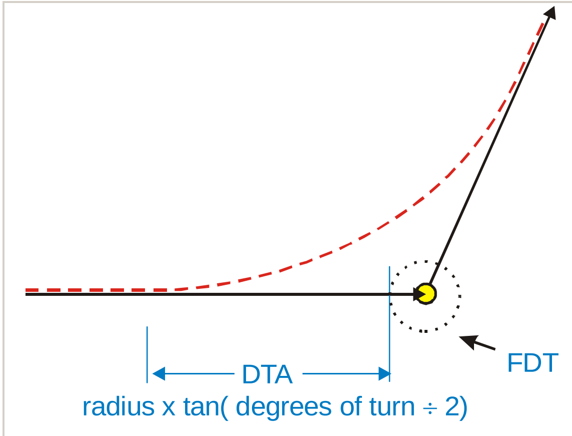
1.5.8 Departure End of Runway (DER).

The DER is the end of the runway that is opposite the landing threshold. It is sometimes referred to as the stop end of runway.

1.5.9 Distance of Turn Anticipation (DTA).

DTA represents the maximum distance from (prior to) a fly-by-fix that an aircraft is expected to start a turn to intercept the course of the next segment. The along-track FDT value associated with a fix is added to the DTA value when DTA is applied (see figure 1-4).

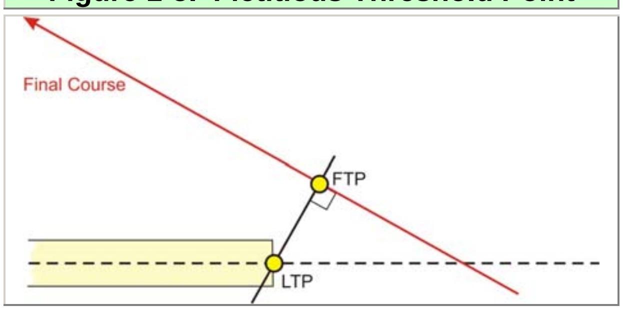
Figure 1-4. Distance of Turn Anticipation



1.5.10 Fictitious Threshold Point (FTP).

The FTP is the equivalent of the landing threshold point (LTP) when the final approach course is offset from the runway centerline. It is the intersection of the final course and a line perpendicular to the final course that passes through the LTP. FTP elevation is the same as the LTP (see figure 1-5). For the purposes of this document, where LTP is used, FTP may apply as appropriate.

Figure 1-5. Fictitious Threshold Point



1.5.11 Fix Displacement Tolerance (FDT).

FDT is a quantification of ATRK and XTRK positioning error defined as a circular area centered on an RNAV fix (see figure 1-4).

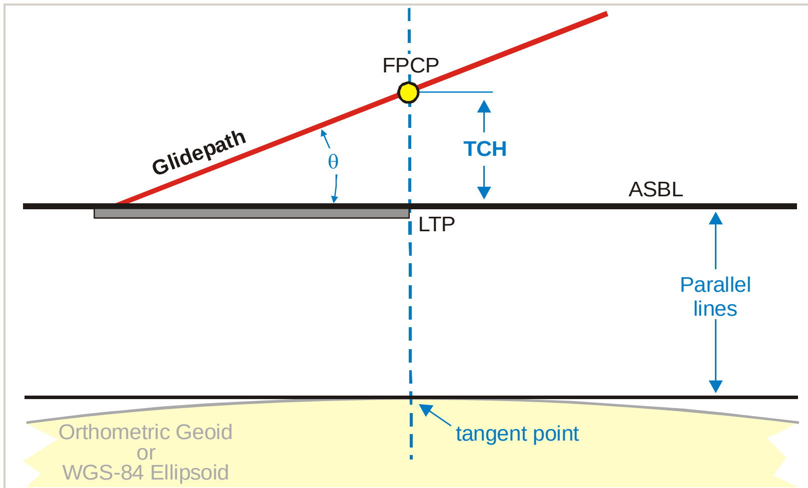
1.5.12 Flight Path Alignment Point (FPAP).

The FPAP is a 3D point defined by World Geodetic System (WGS)-84/North American Datum (NAD)-83 latitude, longitude, MSL elevation, and WGS-84 geoid height. The FPAP is used in conjunction with the LTP and the geometric center of the WGS-84 ellipsoid to define the glidepath's vertical plane associated with an RNAV final course.

1.5.13 Flight Path Control Point (FPCP).

The FPCP is a 3D point defined by the LTP or FTP latitude/longitude position, MSL elevation, and a threshold crossing height (TCH) value. The FPCP is in the vertical plane associated with the final approach course and is used to relate the glidepath angle of the final approach track to the landing runway. It is sometimes referred to as the TCH point or reference datum point (RDP) (see figure 1-6).

Figure 1-6. FPCP, TCH, GPA (θ)



1.5.14 Geoid Height (GH).

The GH is the height of the geoid (reference surface for MSL heights) relative to the WGS-84 ellipsoid. It is a positive value when the geoid is above the WGS-84 ellipsoid and negative when it is below. The value is used to convert an MSL elevation to an ellipsoidal or geodetic height - the height above ellipsoid (HAE).

1.5.15 Glidepath Angle (GPA).

The GPA is the angle of the specified final approach descent path relative to the ASBL (see figure 1-6). In this order, the glidepath angle is represented in formulas and figures as the Greek symbol theta **(θ).**

1.5.16 Glidepath Qualification Surface (GQS).

The GQS is a narrow inclined plane centered on the runway centerline that limits the height of obstructions between the DA and LTP. A clear GQS is required for authorization of vertically guided approach procedure development.

1.5.17 Height above Ellipsoid (HAE).

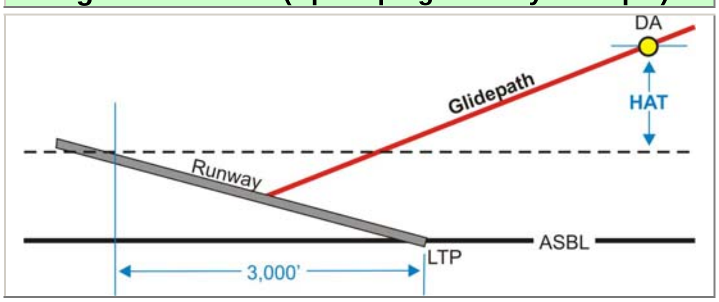
The elevation of the glidepath origin (TCH point) for an LPV approach procedure is referenced to the LTP. RNAV avionics calculate heights relative to the WGS-84 ellipsoid. Therefore, it is important to specify the HAE value for the LTP. This value differs from a height expressed in feet above the geoid (essentially MSL) because the reference surfaces (WGS-84 ellipsoid and the geoid) do not coincide. Ascertain the height of the orthometric geoid (MSL surface) relative to the WGS-84 ellipsoid at the LTP. This value is considered the GH. For Westheimer Field, Oklahoma the GH is –87.29 ft. This means the geoid is 87.29 ft BELOW the WGS-84 ellipsoid at the latitude and longitude of the runway 35 threshold. To convert an MSL height to an HAE height, algebraically add the geoid height value to the MSL value. HAE elevations are not used for instrument procedure construction, but are documented for inclusion in airborne receiver databases.

EXAMPLE		
Given:	KOUN RWY 35	Runway ID
	N 35 14 31.65	Latitude
	W 97 28 22.84	Longitude
	1177.00	MSL Elevation
	-87.29 ft (-26.606 m)	Geoid Height (GH)
	HAE = MSL+GH	
	HAE = 1,177+(-87.29)	
	HAE = 1,089.71	

1.5.18 Height above Touchdown (HAT).

The HAT is the height of the DA above the highest point in the first 3,000 ft of the landing runway (touchdown zone elevation). See figure 1-7.

Figure 1-7. HAT (Up-Sloping Runway Example)



1.5.19 Inner-Approach Obstacle Free Zone (OFZ).

The inner-approach OFZ is the airspace above a surface centered on the extended runway centerline. It applies to runways with an approach lighting system of any authorized type. (USAF NA)

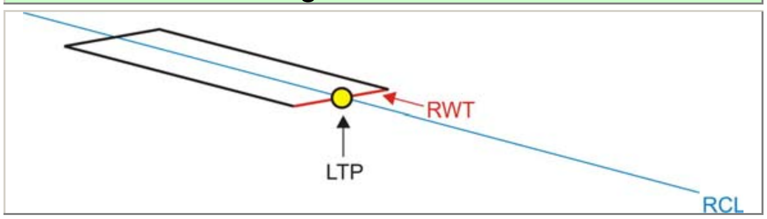
1.5.20 Inner-Transitional OFZ.

The inner-transitional OFZ is the airspace above the surfaces located on the outer edges of the runway OFZ and the inner-approach OFZ. It applies to runways with approach visibility minimums less than ¾ statute mile. (USAF NA)

1.5.21 Landing Threshold Point (LTP).

The LTP is a 3D point at the intersection of the runway centerline and the runway threshold (RWT). WGS-84/NAD-83 latitude, longitude, MSL elevation, and geoid height define it (see figure 1-2). It is used in conjunction with the FPAP and the geometric center of the WGS-84 ellipsoid to define the vertical plane of an RNAV final approach course. LTP elevation (LTP_E) applies to the LTP and FTP when the final approach course is offset from runway centerline. For the purposes of this document, where LTP is used, FTP may apply as appropriate (see figure 1-8). (USAF must use WGS-84 latitude and longitude only.)

Figure 1-8. LTP



1.5.22 Lateral Navigation (LNAV).

LNAV is RNAV lateral navigation. This type of navigation is associated with nonprecision approach procedures (NPA) because vertical path deviation information is not provided. LNAV criteria are the basis of the LNAV minima line on RNAV GPS approach procedures.

1.5.23 LNAV/VNAV Final Approach.

An APV approach that is evaluated using the Baro VNAV obstacle clearance surfaces conforming to the lateral dimensions of the LNAV obstruction evaluation area (OEA). The final descent can be flown using Baro VNAV, LPV, or WAAS precision vertical guidance in accordance with AC 90-97, Operational Approval of Barometric VNAV Instrument Approach Operations Using Decision Altitude.

1.5.24 Localizer Performance with Vertical Guidance (LPV).

An LPV approach is an RNAV procedure evaluated using the lateral obstacle clearance surface (OCS) dimensions (horizontal and vertical) of the precision approach trapezoid. These procedures are published on RNAV GPS approach charts as the LPV minima line.

1.5.25 Obstacle Evaluation Area (OEA).

An area within defined limits that is subjected to obstacle evaluation through application of required obstacle clearance (ROC) or an OCS.

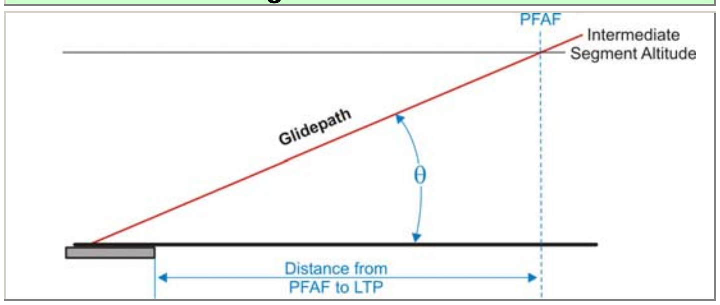
1.5.26 Obstacle Clearance Surface (OCS).

An OCS is an upward or downward sloping surface used for obstacle evaluation where the flight path is climbing or descending. The separation between this surface and the vertical path angle defines the MINIMUM required obstruction clearance at that point.

1.5.27 Precision Final Approach Fix (PFAF).

A calculated WGS-84 geographic position located on the final approach course where the glidepath intercepts the intermediate segment altitude (glidepath intercept altitude). The PFAF marks the beginning of the final approach segment (FAS) of a PA, APV, or LNAV approach procedure (see figure 1-9). The calculation of the distance from LTP to PFAF includes the earth curvature.

Figure 1-9. PFAF



1.5.28 Runway Threshold (RWT).

The RWT marks the beginning of the part of the runway that is usable for landing (see figure 1-8). It includes the entire width of the runway.

1.5.29 Threshold Crossing Height (TCH).

The height of the glidepath above the threshold of the runway measured in feet (see figure 1-6). The LPV glidepath originates at the TCH value above the LTP.

1.5.30 Touchdown Zone Elevation (TDZE).

The TDZE represents the highest elevation in the first 3,000 ft of the landing surface (see figure 1-7).

1.5.31 Visual Glide Slope Indicator (VGSI).

The VGSI is an airport lighting aid that provides the pilot a visual indication of the aircraft position relative to a specified glidepath to a touchdown point on the runway.

1.5.32 Wide Area Augmentation System (WAAS).

The WAAS is a navigation system based on the GPS. Ground correction stations transmit position corrections that enhance system accuracy and add satellite based VNAV features.

1.6 INFORMATION UPDATE.

For your convenience, FAA Form 1320-19, Directive Feedback Information, is included at the end of this order to note any deficiencies found, clarifications needed, or suggested improvements regarding the contents of this order. When forwarding your comments to the originating office for consideration, please use the "Other Comments" block to provide a complete explanation of why the suggested change is necessary.

CHAPTER 2. GENERAL CRITERIA

SECTION 1. BASIC CRITERIA INFORMATION

2.0 GENERAL.

The following FAA orders apply unless otherwise specified in this order:

2.0.1 **8260.3,** United States Standard for Terminal Instrument Procedures (TERPS).

2.0.2 **8260.19**, Flight Procedures and Airspace.

2.0.3 **7130.3**, Holding Pattern Criteria.

The final and missed approach criteria described in this order supersede the other publications listed above, except as noted.

2.1 DATA RESOLUTION.

Perform calculations using <u>at least</u> 0.01 unit of measure accuracy. When calculating by automated means, use a calculation accuracy of at least 13 significant digits. The following list specifies the minimum accuracy standard for <u>documenting</u> data expressed numerically. This standard applies to the documentation of final results only; e.g., a calculated adjusted glidepath angle of 3.04178° is documented as 3.05°. The standard does not apply to the use of variable values during calculation. Use the most accurate data available for variable values.

**Do not round intermediate results. Round only the final result of calculations for documentation purposes.*

2.1.1 Documentation Accuracy:

2.1.1 **a. WGS-84 latitudes and longitudes** to the nearest one hundredth (0.01) arc second; *[nearest five ten thousandth (0.0005) arc second for FAS data block entries]*.

2.1.1 **b LTP MSL elevation** to the nearest foot;

2.1.1 **c. LTP height above ellipsoid (HAE)** to the nearest tenth (0.1) meter;

2.1.1 **d. Glidepath angle** to the next higher one hundredth (0.01) degree;

2.1.1 **e. Courses** to the nearest one hundredth (0.01) degree; and

2.1.1 **f. Course width at threshold** to the nearest quarter (0.25) meter;

2.1.1 **g. Distances** to the nearest hundredth (0.01) unit *[except for "length of offset" entry in FAS data block which is to the nearest 8 meter value]*.

**Use the documented rounded values in paragraphs 2.1.1a through g in calculations*.

2.1.2 Mathematics Convention.

2.1.2 a. Definition of Mathematical Functions.

$a + b$ indicates addition
$a - b$ indicates subtraction
$a \times b$ or ab indicates multiplication
$\frac{a}{b}$ or a/b or $a \div b$ indicates division
$(a - b)$ indicates the result of the process within the parenthesis
$|a - b|$ indicates absolute value
$\approx$ indicates approximate equality
$\sqrt{a}$ indicates the square root of quantity "a"
a^2 indicates $a \times a$
$\tan(a)$ indicates the tangent of "a" degrees
$\tan^{-1}(a)$ indicates the arc tangent of "a"
$\sin(a)$ indicates the sine of "a" degrees
$\sin^{-1}(a)$ indicates the arc sine of "a"
$\cos(a)$ indicates the cosine of "a" degrees
$\cos^{-1}(a)$ indicates the arc cosine of "a"

2.1.2 b. Operation Precedence (Order of Operations).

First: Grouping Symbols: parentheses, brackets, braces, fraction bars, etc.
Second: Functions: Tangent, sine, cosine, arcsine and other defined functions
Third: Exponentiations: Powers and roots
Fourth: Multiplication and Division: Products and quotients
Fifth: Addition and subtraction: Sums and differences
e.g,
$5 - 3 \times 2 = -1$ because multiplication takes precedence over subtraction
$(5 - 3) \times 2 = 4$ because parentheses take precedence over multiplication
$\frac{6^2}{3} = 12$ because exponentiation takes precedence over division
$\sqrt{9 + 16} = 5$ because the square root sign is a grouping symbol
$\sqrt{9} + \sqrt{16} = 7$ because roots take precedence over addition
$\frac{\sin(30^\circ)}{0.5} = 1$ because functions take precedence over division
$sin\left(\frac{30^\circ}{0.5}\right) = 0.8660254$ because parentheses take precedence over functions

{ NOTES on calculator usage:

1. Most calculators are programmed with these rules of precedence.
2. When possible, let the calculator maintain all of the available digits of a number in memory rather than re-entering a rounded number. For highest accuracy from a calculator, any rounding that is necessary should be done at the latest opportunity. }

2.1.3 Evaluation of Actual and Assumed Obstacles (AAO).

2.1.3 **a. Accuracy Uncertainty Standards**. Apply the vertical and horizontal accuracy standards in Order 8260.19, paragraphs 272, 273, 274, and appendix 2. If specific terrain information (a site inspection, local information, or site survey, etc.) is not available, apply the following:

- The next higher contour line minus one unit of elevation; or if other terrain data formats are used (e.g. DEMs) instead of terrain contour lines, use the DEM data point value, and

- The higher of:

    - An assumed canopy height consistent with local area vegetation (since canopy height varies throughout the country, verify the height value to use with the FAA regional FPO); or

    - An AAO of 200 ft above the next higher gradient line minus one unit of elevation, unless it penetrates the Code of Federal Regulations (CFR) Part 77 surfaces for which a Part 77 survey has been performed.

NOTE: USAF, apply guidance per AFI 11-230.

2.1.4 Fix Displacement Tolerance (FDT).

FDT is an assumed value for position uncertainty at an RNAV fix. For procedure construction purposes, FDT is considered "circular;" i.e., the value assigned describes a radius around the plotted position of the RNAV fix (see figure 2-1 and table 2-1

Figure 2-1. FDT

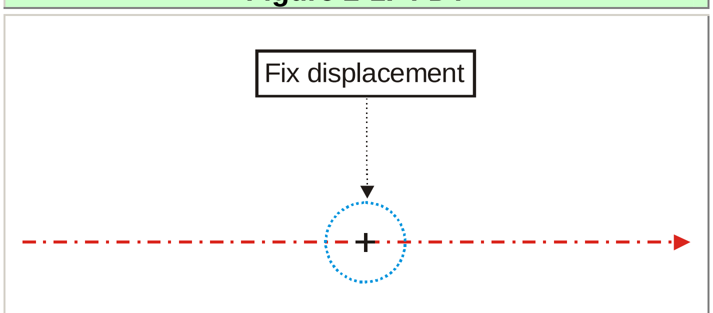


Table 2-1. FDT Values		
GPS	En Route	2.0 NM (12552 ft) (3704 m)
	Terminal	1.0 NM (6076 ft) (1852 m)
	Approach	0.3 NM (1823 ft)(556 m)
LPV*	Approach	0.02 NM (131 ft) (40 m)

*The LPV values apply only to LPV final approach segment. Apply GPS values to all other segments of the approach procedure.

2.2 PROCEDURE IDENTIFICATION.

Title RNAV procedures containing LPV minimums "**RNAV (GPS) RWY XX**." Where more than one RNAV approach is developed to the same runway, identity each with an alphabetical suffix beginning at the end of the alphabet. Title the procedure with the lowest minimums with a "Z" suffix, etc.

Examples

RNAV (GPS) Z RWY 13 (Lowest HAT: example 257 ft)
RNAV (RNP) Y RWY 13 (2^{nd} lowest HAT: example 294 ft)
RNAV (GPS) X RWY 13 (3^{rd} lowest HAT: example 360 ft)

For ILS approach procedures designed with only RNAV initial, intermediate and missed approach segments, standard **ILS RWY XX** naming convention applies; however, the approach must be annotated to require GPS. For conventional ILS procedures with RNAV transitions added, annotate the transition to require GPS.

2.3 SEGMENT WIDTH.

Table 2-2 lists primary and secondary width values for all segments of an RNAV approach procedure. Where segments cross* a point 30 NM from ARP, segment primary area width increases (expansion) or decreases (taper) at a rate of 30° relative to course to the appropriate width (see figure 2-3). Secondary area expansion/taper is a straight-line connection from the point the primary area begins expansion/taper to the point the primary area expansion/taper ends (see figure 2-2). Reference to route width values is often specified as nautical mile (NM) values measured from secondary area edge across the primary area to the secondary edge at the other side. For example, route width for segments more than 30 NM from ARP is "2-4-4-2." For distances ≤ 30 NM, the width is "1-2-2-1." See table 2-2 and figures 2-2 and 2-3.

**NOTE: A segment designed to cross within 30 NM of the ARP more than once does not taper in width until the 30 NM limit is crossed for approach and landing.*

.

Table 2-2. RNAV Linear Segment Width (NM) Values			
Segment		Primary Area Half-Width (p)	Secondary Area (s)
Initial & Missed Approach	> 30 NM from ARP	± 4.00	2.00
		2-4-4-2	
	≤ 30 NM from ARP	± 2.00	1.00
		1-2-2-1	
Intermediate		Continues initial segment width until 2 NM prior to (P)FAF. Then tapers uniformly to final segment width.	Continues initial segment width until 2 NM prior to (P)FAF. Then it tapers to final segment width.

Figure 2-2. Segment Width Variables

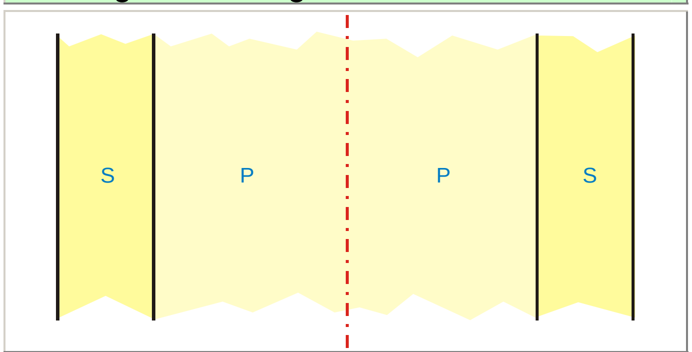
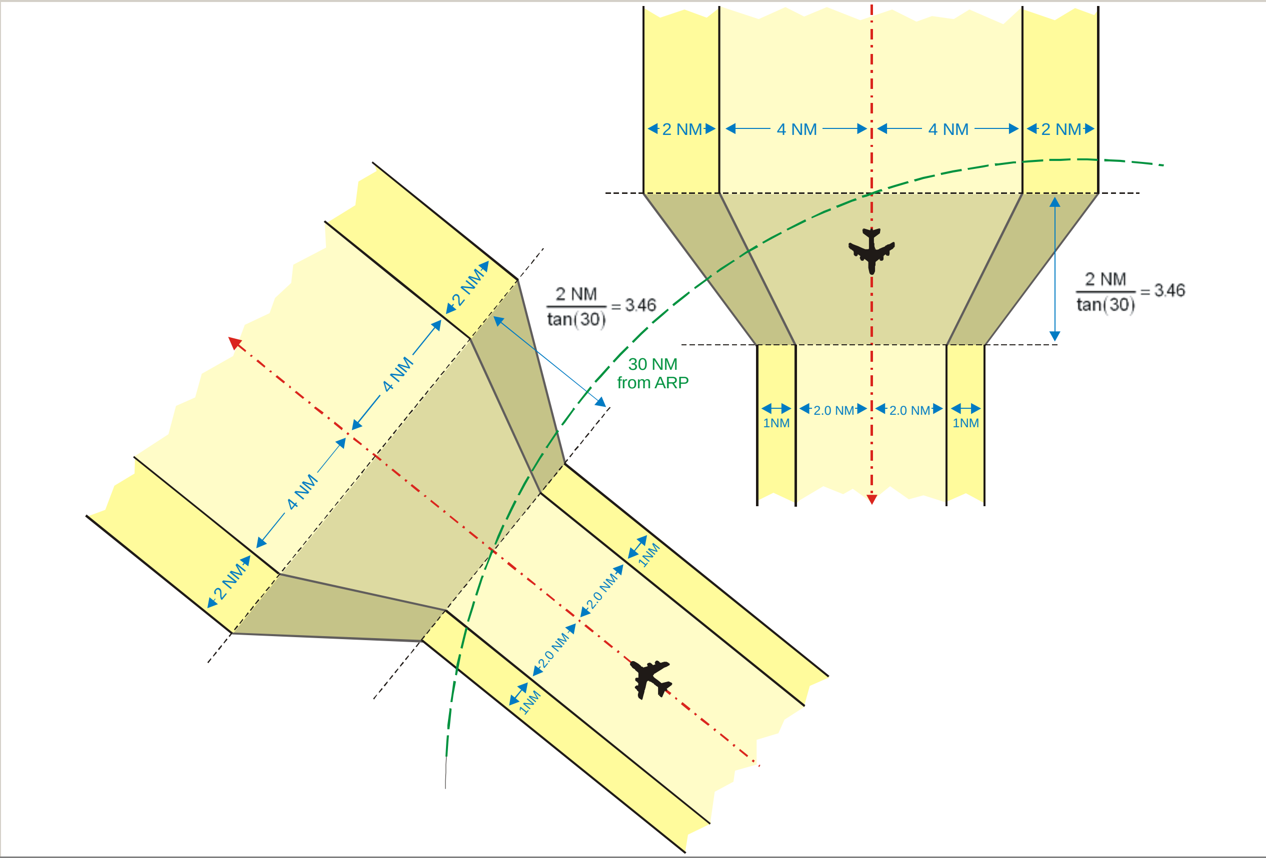


Figure 2-3. Segment Width Changes at 30 NM



2.4 CALCULATING THE TURN RADIUS.

The design turn radius value is based on four variables: indicated airspeed, assumed tailwind, altitude, and bank angle. Apply the indicated airspeed from table 2-3 for the highest speed aircraft category that will be published on the approach procedure. Apply the highest expected turn altitude value. The design bank angle is assumed to be 18°.

STEP 1: Determine the true airspeed (KTAS) for the turn using formula 2-1a. Locate and use the appropriate knots indicated airspeed (KIAS) from table 2-3. Use the highest altitude within the turn.

Formula 2-1a
$V_{KTAS} = V_{KIAS} \times \left[1 + (\textbf{altitude} \times 0.00002)\right]$
Example
Category C initial segment at 6100
$240 \times \left[1 + (6100 \times 0.00002)\right] = 269.28$

Table 2-3. Indicated Airspeeds (Knots)						
Segment		Indicated Airspeed by Aircraft Category (CAT)				
		CAT A	CAT B	CAT C	CAT D	CAT E*
Initial, Intermediate, Missed Approach	Above 10,000	180	250	300	300	350
	At/Below 10,000	150	150	240	250	250
Final		90	120	140	165	As Specified
Missed Approach (MA)		110	150	240	265	As Specified

* Record Cat E indicated airspeed in procedure documentation.

<u>Step 2</u>: Calculate the appropriate tailwind component (**V_{KTW}**) using formula 2-1b for the highest altitude within the turn. Determine **R** using formula 2-2.

Formula 2-1b

$$V_{KTW} = \frac{alt}{500} + 47$$

where alt = MSL elevation

Example

alt = 2300

$$V_{KTW} = \frac{alt}{500} + 47 = 51.6$$

Formula 2-2

$$R = (V_{KTAS} + V_{KTW})^2 \times 0.0000449$$

Example

Cat D aircraft Alt = 6100

$$(280.5 + 59.2)^2 \times 0.0000449 = 518$$

**Greater tailwind component values may be used where data indicates higher wind conditions are likely to be encountered. Where a higher value is used, it must be recorded in the procedure documentation.*

2.5 TURN CONSTRUCTION.

2.5.1 Turns at Fly-Over Fixes (see figures 2-4 and 2-5).

2.5.1 **a. Extension for Turn Delay**.

Turn construction incorporates a delay in start of turn to account for pilot reaction time and roll-in time (rr). Calculate the extension distance in feet using formula 2-3.

Formula 2-3
$rr = 1013 \times V_{KTAS}$
Example
Considering Category D @ 265 KIAS at 3100 feet
$rr = 1013 \times 281.43 = 2850.89$

Step 1. Determine Turn Radius (**R**). See formula 2-2.

Step 2. Determine **rr**. See formula 2-3.

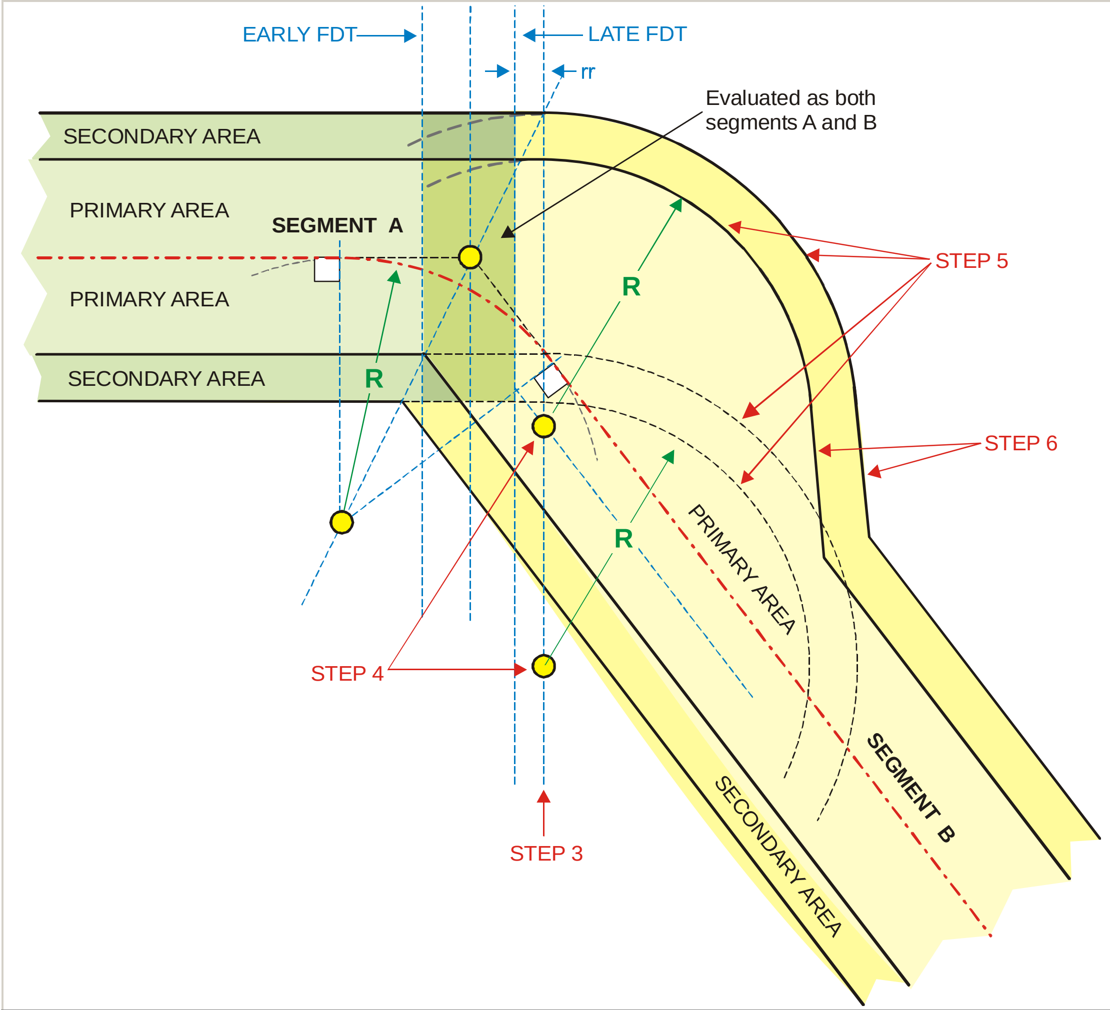
Step 3. Establish the baseline for construction of the turn expansion area as the line perpendicular to the inbound track at a distance past the turn fix equal to (FDT+rr).

Step 4. On the baseline, locate the center points for the primary and secondary turn boundaries. The first is located at a distance **R** from the non-turning side primary boundary. The second is located at a distance **R** from the turning side secondary boundary (see figures 2-4 and 2-5).

Step 5. From these center points construct arcs of radius **R**. Complete the secondary boundary by constructing additional arcs of radius ($\mathbf{R}+\mathbf{W_S}$) from the same center points. ($\mathbf{W_S}$=width of the secondary). This is shown in figures 2-4 and 2-5.

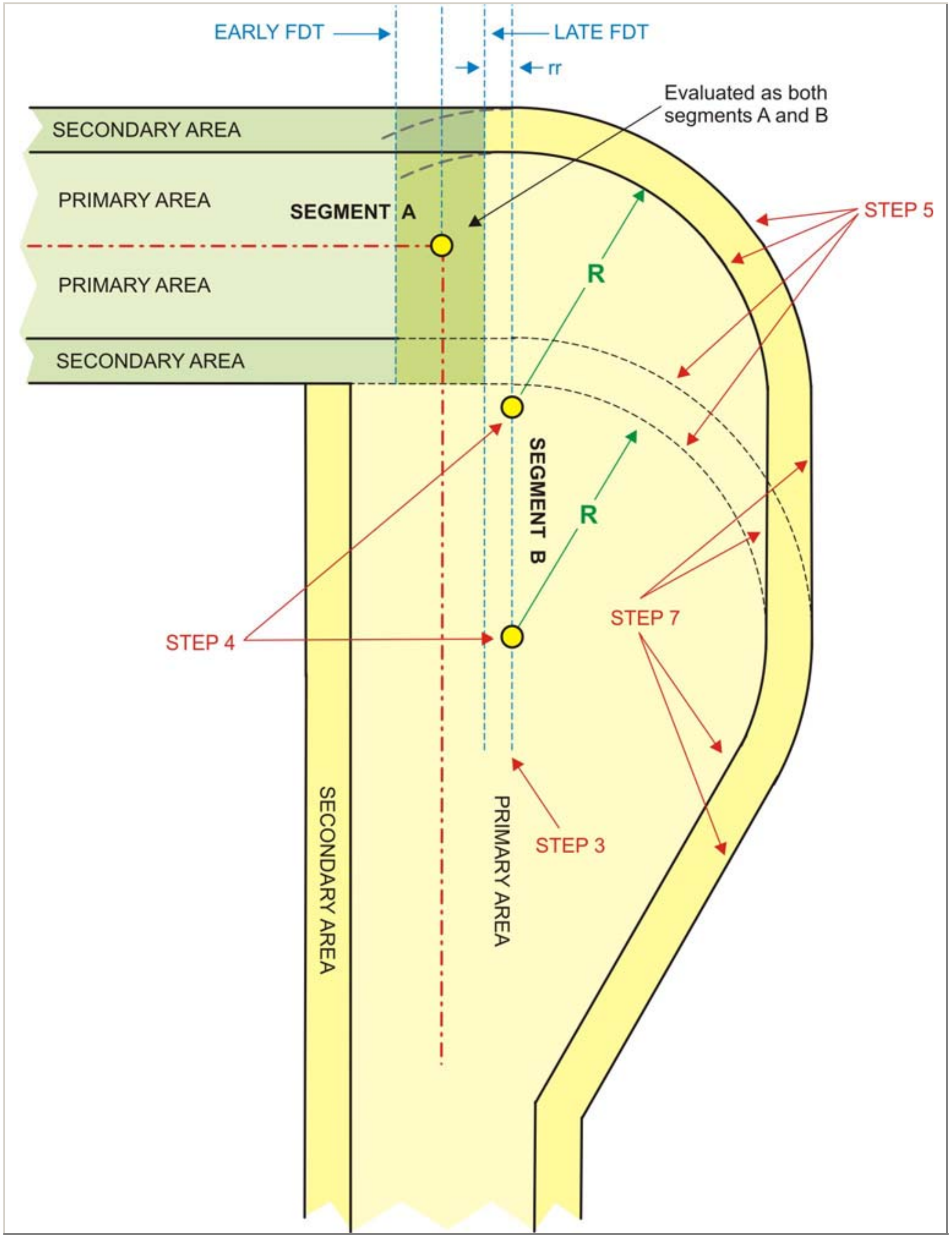
Step 6. Construct lines tangent to the arcs based on the first turn point tapering inward at an angle of 30° relative to the outbound track that joins the arc primary and secondary boundaries with the outbound segment primary and secondary boundaries. If the arcs from the second turn point are inside the tapering lines as shown in figure 2-4, then they are disregarded and the expanded area construction is completed. If not, proceed to step 7.

Figure 2-4. Fly-Over with No Second Arc Expansion



Step 7. If both the inner and outer arcs lie outside the tapering lines constructed in step 6, connect the respective inner and outer arcs with tangent lines and then construct the tapering lines from the arcs centered on the second center point as shown in figure 2-5.

Figure 2-5. Fly-Over with Second Arc Expansion



2.5.1 **b. Minimum length of TF leg following a fly-over turn.** The leg length of a TF leg following a fly-over turn must be sufficient to allow the aircraft to return to course centerline. The minimum length for turns up to 15° is the FDT values at each fix. Where the turn is >15°, determine the minimum leg length using formula 2-4.

Formula 2-4

$$\mathbf{L} = \mathbf{f}\left(\cos(\phi) + \sqrt{3} \bullet \sin(\phi)\right) + \mathbf{R}\left(\sin(\phi) + 2.267949 - \sqrt{3} \bullet \cos(\phi)\right)$$

where R = Turn radius (NM) from formula 2-2

ϕ = degrees of defined track change at fix

f = Fix Displacement Tolerance (NM)

Example

f = 1 r = 5.18 ϕ = 55°

$$\mathbf{L} = 1\left(\cos(55) + \sqrt{3} \bullet \sin(55)\right) + 518\left(\sin(55) + 2.267949 - \sqrt{3} \bullet \cos(55)\right) = 12.84$$

2.5.2 **Fly-By Turn.** See figure 2-6.

<u>Step 1</u>. Determine Turn Radius (**R**). See formula 2-2. Scribe an arc of radius **R** tangent to inbound and outbound courses. This is the designed turning flight path.

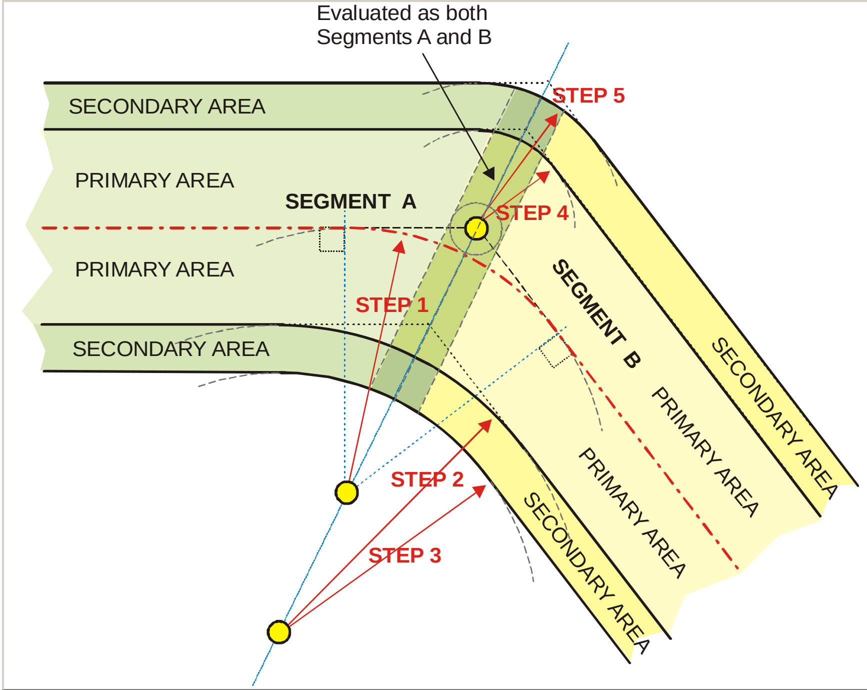
<u>Step 2</u>. Scribe an arc that is tangent to the inner primary boundaries of the two segment legs with a radius equal to $\frac{\text{Primary Area Half-width}}{2}$ (example: half width of 2 NM, the radius would be R+1.0 NM).

<u>Step 3</u>. Scribe an arc that is tangent to the inner secondary boundaries of the two segment legs using the origin and radius from step 2 minus the secondary width.

Step 4. Scribe the primary area outer turning boundary with an arc with a radius equal to the segment half width centered on the turn fix.

<u>Step 5</u>. Scribe the secondary area outer turning boundary with the arc radius from step 4 plus the secondary area width centered on the turn fix.

Figure 2-6. Fly-By Turn Construction



2.5.2 **a. Minimum length of TF leg following a fly-by turn.** The minimum length for a TF leg following a fly-by turn is the FDT of the fix plus the calculated DTA for the turn plus the FDT for the leg termination fix. For example, an initial segment sub segment contains a fly-by turn of 45° at its initial fix, a 30° fly-by turn at its termination fix, and a turn radius of 4.7 NM. The minimum leg length would be the FDT for the initial fix [1.0] plus the DTA at the initial fix [$4.7 \bullet tan\left(\frac{45}{2}\right)$] plus the DTA for the termination fix [$4.7 \bullet tan\left(\frac{30}{2}\right)$] plus FDT for the termination fix [1.0]. The sum of these values is 5.21 NM ($1.0 + 1.95 + 1.26 + 1.0 = 5.21$).

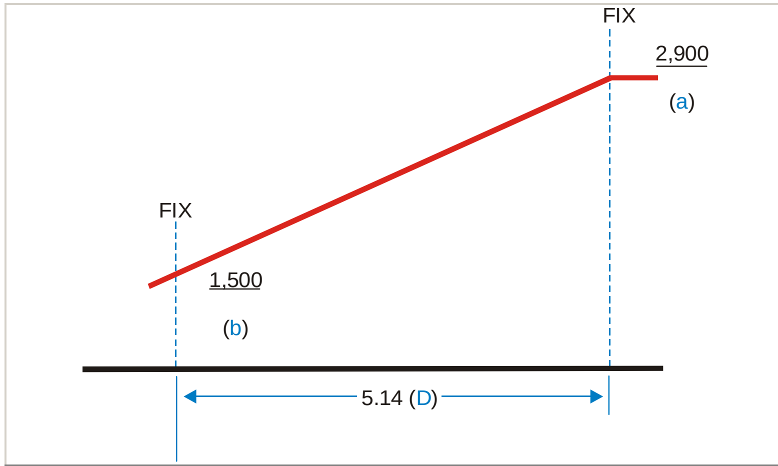
2.6 Descent Gradient.

The OPTIMUM descent gradient in the initial segment is 250 ft/NM (4.11%, 2.356°); MAXIMUM is 500 ft/NM (8.23%, 4.70°). *For high altitude penetrations, the OPTIMUM is 800 ft/NM (13.17%, 7.5°); MAXIMUM is 1,000 ft/NM (16.46%, 9.35°).* The OPTIMUM descent gradient in the intermediate segment is 150 ft/NM (2.47%, 1.41°); MAXIMUM is 318 ft/NM (5.23%, 3.0°).

2.6.1 Calculating Descent Gradient (DG).

Determine total altitude lost between the plotted positions of the fixes. Determine the distance (D) in NM available for descent. Divide the total altitude lost by D to determine the segment descent gradient (see figure 2-7 and formula 2-5).

Figure 2-7. Calculating Descent Gradient



Formula 2-5

$$DG = \frac{a - b}{D}$$

where a = beginning altitude

b = ending altitude

D = distance between fixes

Example

a = 2900 b = 1500 D=5.14

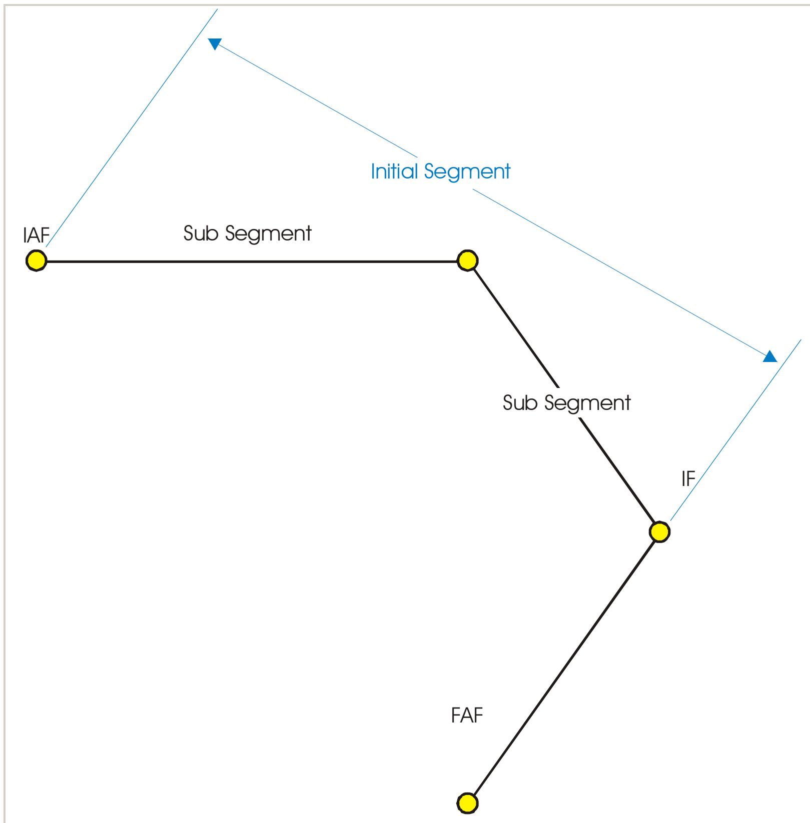
$$\frac{2900-1500}{5.14} = 272.37$$

SECTION 2. TERMINAL SEGMENTS

2.7 INITIAL SEGMENT.

The initial segment begins at the IAF and ends at the IF. The initial segment may contain sequences of straight sub segments (see figure 2-8). Paragraphs 2.7.2, 2.7.3, 2.7.4, and 2.7.5 apply to all sub segments individually. The total length of all sub segments must not exceed 50 NM. Design an arrival holding pattern at the IAF if required.

Figure 2-8. Initial Sub Segments



2.7.1 Course Reversal.

The OPTIMUM design incorporates the basic “T” configuration. This design eliminates the need for a specific course reversal pattern. Where the basic “T” is not used and a course reversal is required, establish a holding pattern at the intermediate fix. The MAXIMUM course change at the fix (IAF/IF) is limited to 15°.

2.7.2 Alignment.

Design initial/initial and initial/intermediate segment intersections with the smallest amount of course change that is necessary for the procedure (zero is OPTIMUM). The MAXIMUM course change between TF segments is 90°. The MAXIMUM course change from initial to intermediate segment is 90°; however, intercept should be limited to 30° unless obstructions preclude the construction.

2.7.3 Area – <u>Length</u>.

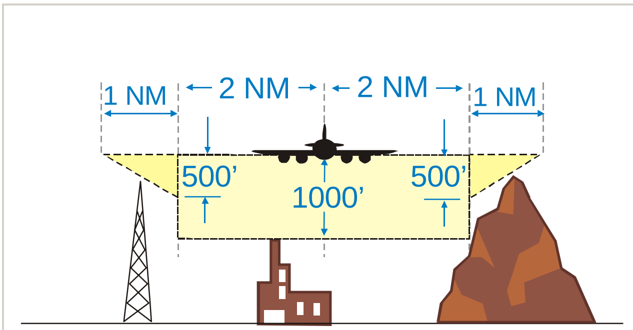
The MAXIMUM segment length (total of sub segments) is 50 NM. Minimum length of sub segments is determined as described in paragraphs 2.5.1b and 2.5.2a.

2.7.4 Area – <u>Width</u> (see table 2-2).

2.7.5 Obstacle Clearance.

Apply 1,000 ft of ROC over the highest obstacle in the primary OEA. The ROC in the secondary area is 500 ft at the primary boundary tapering uniformly to zero at the outer edge (see figure 2-9).

Figure 2-9. Initial Segment ROC



Calculate the secondary ROC values using formula 2-6.

Formula 2-6

$$ROC_{secondary} = \frac{500(\mathbf{D} - \mathbf{d})}{\mathbf{D}}$$

where D = width of secondary in feet

d = distance (ft) from edge of primary area measured perpendicular to course

Example

d = 1757 D = 3188

$$ROC_{secondary} = \frac{500(3188 - 1757)}{3188} = 224.44$$

2.8 INTERMEDIATE SEGMENT.

The intermediate segment primary and secondary boundary lines connect abeam the plotted position of the PFAF at the appropriate primary and secondary final segment beginning widths.

NOTE: If the procedure supports an LNAV final segment, the FAF and PFAF must be coincident.

2.8.1 Alignment (Maximum Course Change at the PFAF).

Align the intermediate course to the final approach course (zero course change).

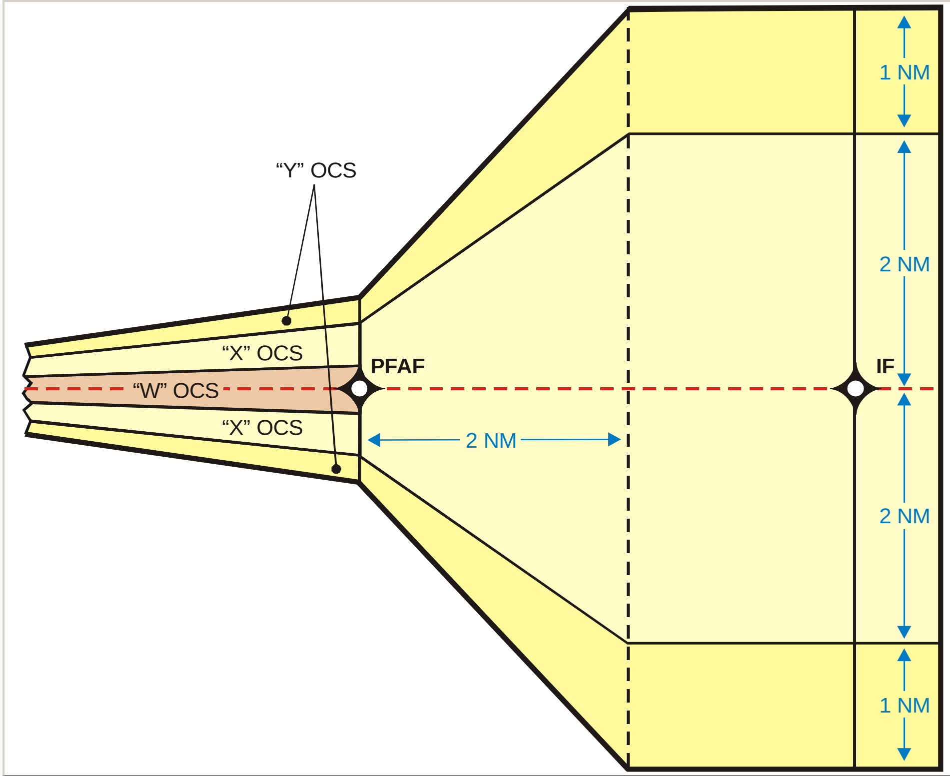
2.8.2 <u>Length</u> (Fix to Fix).

The MINIMUM CAT A/B segment length is 3 NM; the OPTIMUM is 3 NM. The MINIMUM CAT C/D segment length is 4 NM; the optimum is 5. The MINIMUM CAT E segment length is 6 NM. Where turns to and from the intermediate segment are necessary, increase the minimum length values by at least $2tan\left(\frac{\text{turn angle}}{2}\right)$ for each turn. For example, a 60° turn over the intermediate fix requires an increase of 1.15 NM [$2tan\left(\frac{60}{2}\right)=1.15$] to the intermediate segment length. The MAXIMUM length is 10 NM.

2.8.3 Width.

The intermediate segment primary area tapers uniformly from ± 2 NM at a point 2 NM prior to the PFAF to the outer boundary of the X OCS abeam the PFAF. The secondary boundary tapers uniformly from 1 NM at a point 2 NM prior to the PFAF to the outer boundary of the Y OCS abeam the PFAF (see figure 2-10).

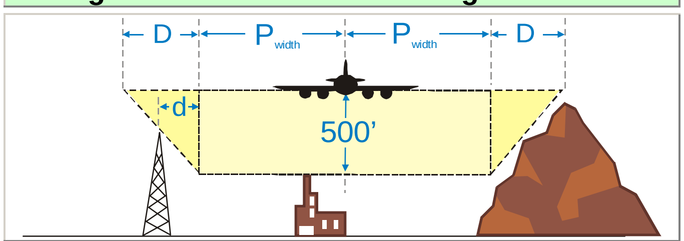
Figure 2-10. Intermediate Segment (LPV / ILS)



2.8.4 Obstacle Clearance.

Apply 500 ft of ROC over the highest obstacle in the primary OEA. The ROC in the secondary area is 500 ft at the primary boundary tapering uniformly to zero at the outer edge (see figure 2-11).

Figure 2-11. Intermediate Segment ROC



Calculate the secondary ROC values using formula 2-6.

2.8.5 **Minimum IF to LTP Distance**.

Locate the IF <u>at least</u> $\mathbf{d_{IF}}$ (NM) from the LTP (see formula 2-7).

Formula 2-7
$\mathbf{d_{IF}} = \mathbf{d} \times \frac{1822.83 - \mathbf{a}}{6076115 \times \mathbf{a}}$
where d = distance (ft) from FPAP to LTP/FTP
a = width of azimuth signal at LTP
(table 2-8, column 5 value)
Example
a = 350 d=9023
$9023 \frac{1822.83 - 350}{6076115 \times 350} = 6.25$

SECTION 3. BASIC VERTICALLY GUIDED FINAL SEGMENT CRITERIA

2.9 AUTHORIZED GLIDEPATH ANGLES (GPAs).

The OPTIMUM (design standard) glidepath angle is 3°. Glidepath angles greater than 3° that conform to table 2-4 are authorized without Flight Standards/military authority approval only when obstacles prevent use of 3°. Flight Standards or appropriate military approval is required for angles less than 3° or for angles greater than the minimum angle (≥3°) required for obstacle clearance. Note: USAF only – apply guidance per AFI 11-230.

Table 2-4.
Maximum Allowable GPAs

Category	θ
A (80 knots or less)	6.4
A (81-90 knots)	5.7
B	4.2
C	3.6
D&E	3.1

Table 2-5 lists the MINIMUM authorized visibility by aircraft category.

Table 2-5. Standard LPV Landing Minimums

GLIDEPATH ANGLE* (WITH APPROACH LIGHT CONFIGURATION)		MINIMUM HAT	AIRCRAFT CATEGORY			
			A	B	C	D & E
			MINIMUM VISIBILITY			
3.00° — 3.10°	♦	200	¾ 4000			
	#	200	½ 2400			
	$	200	1800			
3.11° – 3.30°	♦	200	¾ 4000		NA	
	♦	250	¾ 4000		1 5000	NA
	#	200	½ 2400		NA	
	#	250	½ 2400		¾ 4000	NA
	$	200	1800		NA	
	$	250	1800		½ 2400	NA
3.31° - 3.60°	♦	200	¾ 4000		NA	
	♦	270	¾ 4000		1 5000	NA
	#	200	½ 2400		NA	
	#	270	½ 2400		¾ 4000	NA
	$	200	2000		NA	
	$	270	2000		½ 2600	NA
3.61° - 3.80°	♦	200	¾ 4000		NA	
	#	200	½ 2400			
3.81° - 4.20°	♦	200	¾ 4000	NA		
	♦	250	¾ 4000	1 5000	NA	
	#	200	½ 2400	NA		
	#	250	½ 2400	¾ 4000		
4.21° - 5.0°	♦	250	¾ 4000	NA		
	#	250	½ 2400			
5.01° - 5.70°	♦	300	1 5000			
	#	300	¾ 4000			
5.71° — 6.40° AIRSPEED NTE 80 KNOTS	♦	350	1 ¼			
	#	350	1 5000			

♦ = No Lights $ = # Plus TDZ/CL Lights   # = MALSR, SSALR, ALSF   NA = Not authorized

NOTE: For a HAT higher than the minimum, the visibility (prior to applying credit for lights) must equal the distance MAP to threshold, or (a) 3/4 mile whichever is the greater.

* *Angles less than 3° require Flight Standards or appropriate military authority approval.*

Table 2-6 lists the MAXIMUM TCH values for allowing light credit.

Table 2-6. Threshold Crossing Height Upper Limits for Allowing Visibility Credit for Authorized Lighting Systems

HAT (Feet)	**GLIDEPATH ANGLE (Degrees)**	**TCH UPPER LIMIT (Feet)**	**HAT (Feet)**	**GLIDEPATH ANGLE (Degrees)**	**TCH UPPER LIMIT (Feet)**
200	3.00 - 3.20	75	300	3.00 - 4.90	75
	3.21 - 3.30	70		4.91 - 5.00	71
	3.31 - 3.40	66		5.01 - 5.10	66
	3.41 - 3.50	63		5.11 - 5.20	61
	3.51 - 3.60	59		5.21 - 5.30	56
	3.61 - 3.70	55		5.31 - 5.40	52
	3.71 - 3.80	50		5.41 - 5.50	48
	3.81 - 3.90	47		5.51 - 5.60	43
	3.91 - 4.00	43		5.61 - 5.70	39
	4.01 - 4.10	39			
	4.11 - 4.20	35	350	3.00 - 5.60	75
				5.61 - 5.70	70
250	3.00 - 4.10	75		5.71 - 5.80	65
	4.11 - 4.20	71		5.81 - 5.90	60
	4.21 - 4.30	67		5.91 - 6.00	55
	4.31 - 4.40	62		6.01 - 6.10	50
	4.41 - 4.50	58		6.11 - 6.20	45
	4.51 - 4.60	54		6.21 - 6.30	40
	4.61 - 4.70	50		6.31 - 6.40	35
	4.71 - 4.80	45			
	4.81 - 4.90	41			
	4.91 - 5.00	37			
270	3.00 - 4.40	75			
	4.41 - 4.50	73			
	4.51 - 4.60	68			
	4.61 - 4.70	64			
	4.71 - 4.80	59			
	4.81 - 4.90	55			
	4.91 - 5.00	51			

2.10 THRESHOLD CROSSING HEIGHT (TCH).

Select the appropriate TCH from table 2-7. Publish a note indicating visual glide slope indicator (VGSI) not coincident with the procedure GPA when the VGSI angle is more than 0.2° from the LPV GPA, or when the VGSI TCH is more than 3 ft from the LPV TCH.

Table 2-7. TCH Requirements

Representative Aircraft Type	Approximate Glidepath-to-Wheel Height	Recommended TCH ± 5 Ft	Remarks
HEIGHT GROUP 1 General Aviation, Small Commuters, Corporate turbojets: T-37, T-38, C-12, C-20, C-21, T-1, T-3, T-6, UC-35, Fighter Jets	10 ft or less	40 ft	Many runways less than 6,000 ft long with reduced widths and/or restricted weight bearing which would normally prohibit landings by larger aircraft.
HEIGHT GROUP 2 F-28, CV-340/440/580, B-737, C-9, DC-9, C-130, T-43, B-2, S-3	15 ft	45 ft	Regional airport with limited air carrier service.
HEIGHT GROUP 3 B-727/707/720/757, B-52, C-17, C-32, C-135, C-141, E-3, P-3, E-8	20 ft	50 ft	Primary runways not normally used by aircraft with ILS glidepath-to-wheel heights exceeding 20 ft.
HEIGHT GROUP 4 B-747/767/777, L-1011, DC-10, A-300, B-1, KC-10, E-4, C-5, VC-25	25 ft	55 ft	Most primary runways at major airports.

NOTES:

1: To determine the minimum allowable TCH, add 20 ft to the glidepath-to-wheel height.

2: To determine the maximum allowable TCH, add 50 ft to the glidepath-to-wheel height.

2.11 DETERMINING FPAP COORDINATES (LPV ONLY).

The positional relationship between the LTP and the FPAP determines the final approach ground track. Geodetically calculate the latitude and longitude of the FPAP using the LTP as a starting point, the desired final approach course (OPTIMUM course is the runway bearing) as a forward azimuth value, and an appropriate distance (see formulas 2-8, 2-9, and 2-10). Apply table 2-8 to determine the appropriate distance from LTP to FPAP, signal splay, and course width at LTP.

Table 2-8. FPAP Information					
1	**2**	**3**	**4**	**5**	**6**
ILS Serves Runway **LTP Distance to LOC**	**ILS Does Not Serve Runway** **Runway Length**	**FPAP Distance from LTP**	**± Splay**	**± Width**	**Length Offset**
≤ 10,023'	≤ 9,023'	9,023'	2.0° **	350 ft (106.75 m)* **	Formula 2-10 **
> 10,023' and ≤ 13,366'	> 9,023' and ≤ 12,366'	to DER	Formula 2-8* **		0 **
> 13,366 and ≤ 17,185'	> 12,366 and ≤ 16,185'		1.5° **	Formula 2-9* **	0 **
> 17,185' (AFS or Appropriate Military Agency Approval)	> 16,185' (AFS or Appropriate Military Agency Approval)	to DER or as specified by approving agency			0 **

* Round result to the nearest 0.25 meter

** Use the ILS database values if applying column 1

Formula 2-8

$$\tan^{-1}\left(\frac{350}{\textbf{RWY length}+1000}\right)$$

Example

$$\tan^{-1}\left(\frac{350}{11250+1{,}000}\right)=1.64°$$

Formula 2-9

$$0.0079815(\textbf{RWY length}+1{,}000)$$

round result to nearest 0.25 meters

Derivation

$$\frac{\tan(1.5)(\textbf{RWY}\ \text{length}+1{,}000)}{3.2808}$$

Example

$0.0079815\times(15000+1000)=127.70$ meters

rounds to 127.75 m

Formula 2-10

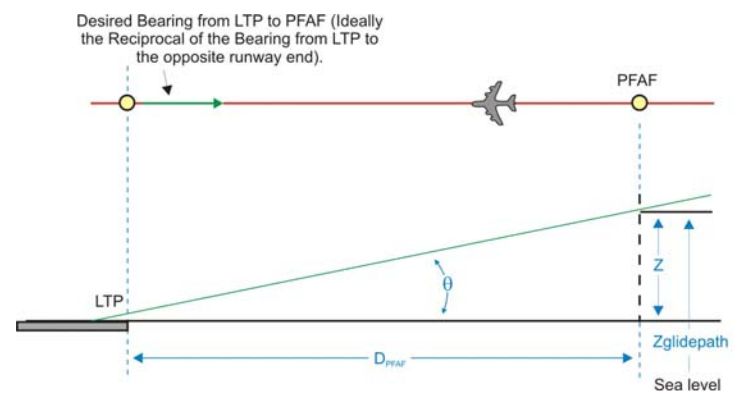
$$\textbf{FPAP}_{\text{Distance}}-\textbf{RWY}\ \text{length}$$

Example

9023 - 5955 = 3068

2.12 DETERMINING PRECISION FINAL APPROACH FIX/FINAL APPROACH FIX (PFAF/FAF) COORDINATES. See figure 2-12.

Figure 2-12. Determining PFAF Distance to LTP



Geodetically calculate the latitude and longitude of the PFAF using the true bearing from the landing threshold point (LTP) to the PFAF and the horizontal distance (**D_{PFAF}**) from the LTP to the point the glidepath intercepts the intermediate segment altitude. Determine **D_{PFAF}** using formula 2-11*{includes earth curvature}*:

Formula 2-11

$$D_{PFAF} = 364609\left[90 - \theta - \sin^{-1}\left(\frac{\sin(90+\theta)20890537}{(a - b - tch) + 20890537}\right)\right]$$

Where: a = minimum intermediate altitude

b = LTP elevation in feet

θ = glidepath angle

tch = threshold crossing height

Example

a = 2000 b = 400 tch = 52 θ = 3°

$$D_{PFAF} = 364609\left[90 - 3 - \sin^{-1}\left(\frac{\sin(90+3)20890537}{(2000-400-52)+20890537}\right)\right] = 29147.45$$

2.13 DETERMINING GLIDEPATH ALTITUDE AT A FIX.

Calculate the altitude ($\mathbf{Z_{glidepath}}$) of the glidepath at any distance ($\mathbf{D_Z}$) from the LTP using formula 2-12 *{includes earth curvature}.*

Formula 2-12

$$Z_{glidepath} = \frac{\cos(\theta)(r + L + TCH)}{\cos\left(\theta + \frac{180 D_Z}{(r + L + TCH)\pi}\right)} - r$$

where r = 20890537

θ = glidepath angle

D_Z = Distance in feet from LTP to fix

L = LTP elevation above mean sea level

$Z_{glidepath}$ = glidepath MSL altitude at fix

Example

$$Z_{glidepath} = \frac{\cos(3)(20890537 + 400 + 52)}{\cos\left(3 + \frac{180(29147.45)}{(20890537 + 400 + 52)31415...}\right)} - 20890537 = 2000$$

where θ = 3 degrees

$LTP_{MSLelevaton}$ = 400

D_Z = 29147.45

TCH = 52

2.14 COMMON FIXES.

Design all procedures published on the same chart to use the same sequence of charted fixes.

2.15 CLEAR AREAS AND OBSTACLE FREE ZONES (OFZ).

Airports Division is responsible for maintaining obstruction requirements in AC 150/5300-13, Airport Design. Appropriate military directives apply at military installations. For the purpose of this order, there are two OFZs that apply: the runway OFZ and the inner approach OFZ. The runway OFZ parallels the length of the runway and extends 200 ft beyond the runway threshold. The inner OFZ overlies the approach light system from a point 200 ft from the threshold to a point 200 ft beyond the last approach light. If approach lights are not installed or not planned, the inner approach OFZ does not apply. When obstacles penetrate either the runway or approach OFZ, visibility credit for lights is not authorized, and the lowest authorized HAT and visibility values are (USAF/USN NA):

- For GPA $\leq$ 4.2°: 300-¾
- For GPA $>$ 4.2°: 400-1

2.16 GLIDEPATH QUALIFICATION SURFACE (GQS).

The GQS extends from the runway threshold along the runway centerline extended to the DA point. It limits the height of obstructions between DA and

RWT. When obstructions exceed the height of the GQS, a vertically guided approach is not authorized (see figures 2-13, 2-14, and 2-15).

**NOTE: Where obstructions penetrate the GQS, operations may be possible with aircraft groups restricted by wheel height (requires Flight Standards approval).*

2.16.1 **Area.**

2.16.1 **a. Origin and Length**. The GQS extends from the origin to the DA. The OCS origin is dependent on the TCH value.

- If the TCH > 50, the GQS originates at RWT "**e**" feet above ASBL.

$$\mathbf{e} = \mathbf{TCH} - 50$$

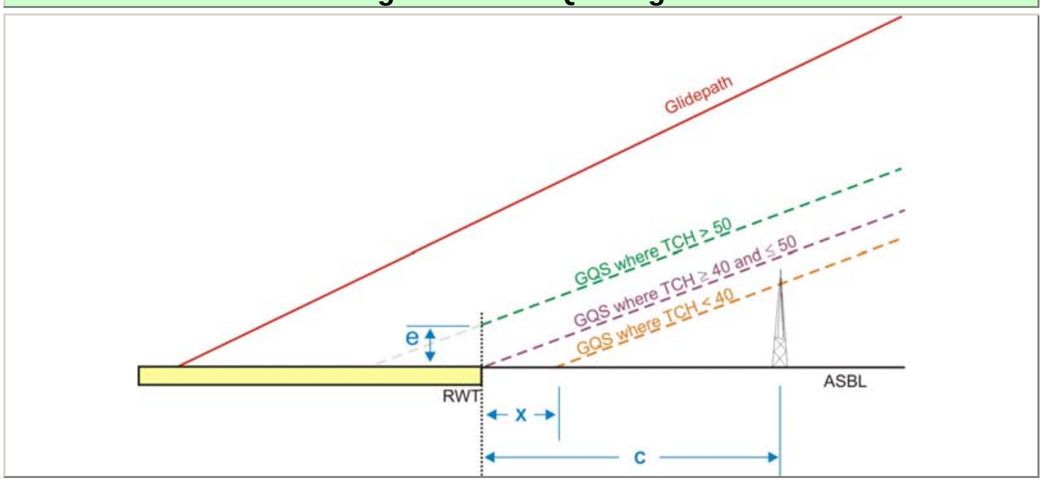
- If the TCH ≥ 40 and ≤ 50, the GQS originates at RWT at ASBL elevation
- If the TCH < 40, the GQS originates "**x**" feet from RWT at ASBL elevation.

$$\mathbf{x} = \frac{40 - \mathbf{TCH}}{tan(\theta)}$$

(Where θ = glide slope angle)

Where X>200', the area between the end of the POFZ and the GQS origin is $\pm \frac{\text{Rwy Width}}{2} + 100'$ wide, centered on the runway centerline extended. Obstacles higher than the clearway plane (see paragraph 2.16.1d) that are not fixed by function for instrument landing operations are not allowed in this area.

Figure 2-13. GQS Origin



2.16.1 **b. Width**. The GQS originates 100 ft from the runway edge at RWT.

Figure 2-14. GQS (TCH≥40)

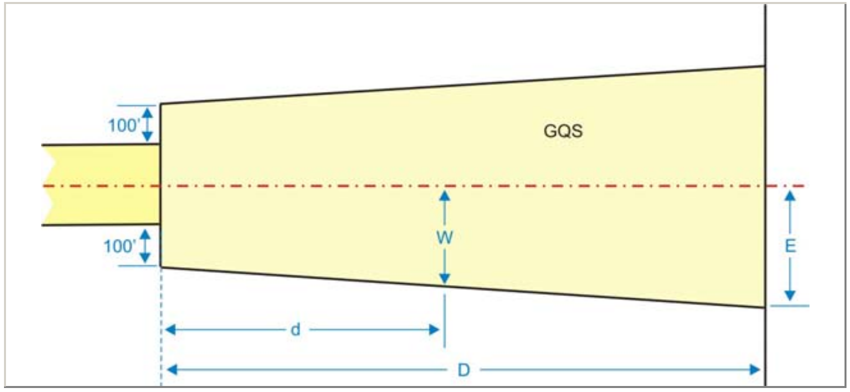
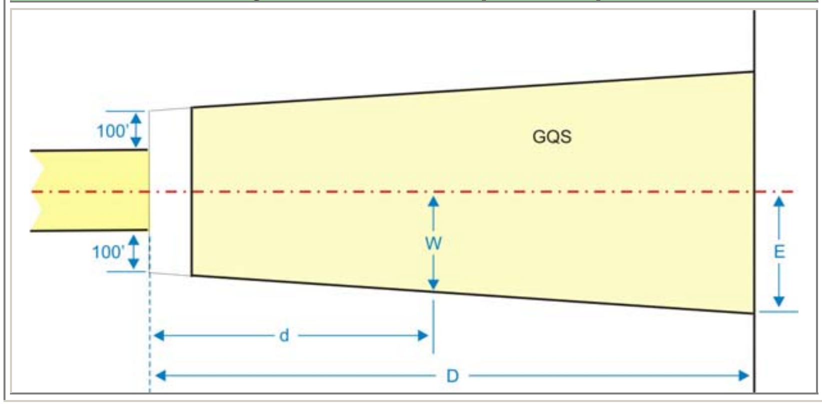


Figure 2-15. GQS (TCH<40)



Calculate the GQS half-width "**E**" at the DA point measured along the runway centerline extended using formula 2-13:

Formula 2-13

$$\mathbf{E} = 0.036\mathbf{D} + 392.8$$

where D = distance (ft) measured along RCL extended from LTP to DA point

Calculate the half-width of the GQS at any distance "d" from RWT using the formula 2-14:

Formula 2-14

$$\mathbf{w} = \left(\frac{\mathbf{E} - \mathbf{k}}{\mathbf{D}}\mathbf{d}\right) + \mathbf{k}$$

where D = Distance (ft) from LTP to DA Point

d = Desired distance (ft) from LTP

w = GQS half-width at distance 'd'

$$k = \frac{\text{RWY Width}}{2} + 100$$

2.16.1 **c. If the course is offset** from the runway centerline, expand the GQS area on the side of the offset as follows referring to figures 2-16 and 2-17:

STEP 1. Construct line **<u>BC</u>**. Locate point "**B**" on the runway centerline extended perpendicular to course at the DA point. Calculate the half-width (E) of the GQS for the distance from point "**B**" to the RWT. Locate point "**C**" perpendicular to the course distance "E" from the course line. Connect points "**B**" and "**C.**"

STEP 2. Construct line **<u>CD</u>**. Locate point "D" 100 ft from the edge of the runway perpendicular to the LTP. Draw a line connecting point "C" to point "D."

STEP 3. Construct line **<u>DF</u>**. Locate point "F" 100 ft from the edge of the runway perpendicular to the LTP. Draw a line connecting point "D" to point "F."

STEP 4. Construct line **<u>AF</u>**. Locate point "A" distance "E" from point "B" perpendicular to the runway centerline extended. Connect point "A" to point "F."

STEP 5. Construct line **<u>AB</u>**. Connect point "A" to point "B."

Figure 2-16. Example: TCH ≥ 40′

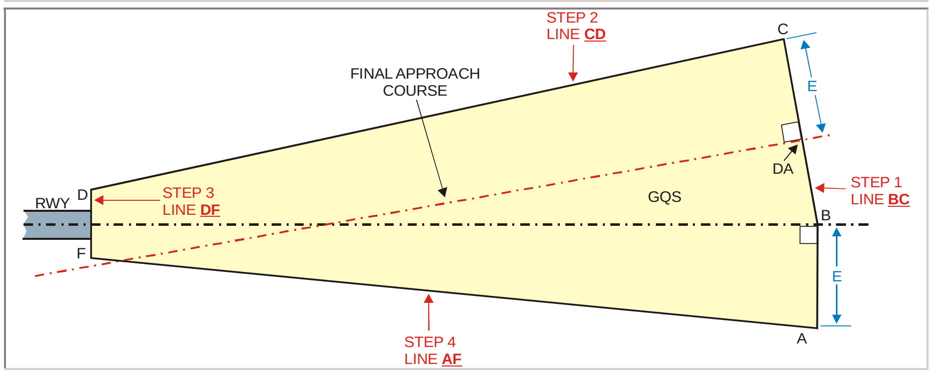
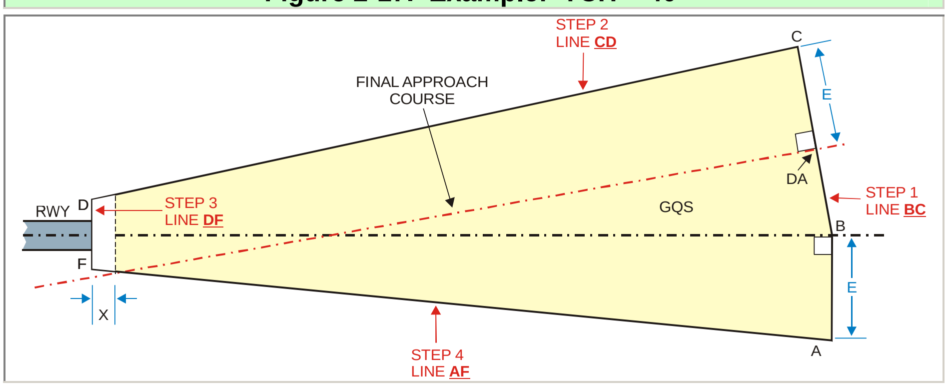


Figure 2-17. Example: TCH < 40′



Calculate the half-width of the offset side of the GQS trapezoid using formula 2-15 (see figure 2-18):

Formula 2-15

$$\mathbf{W_{offset}} = \mathbf{d}\left(\frac{cos(\phi)[sin(\phi)(\mathbf{D}-\mathbf{i})+\mathbf{E}]-\mathbf{k}}{\mathbf{D}-sin(\phi)[sin(\phi)(\mathbf{D}-\mathbf{i})+\mathbf{E}]}\right)+\mathbf{k}$$

where d = distance (ft) from LTP to point in question

D = distance (ft) along RCL from LTP to point B

i = distance (ft) from LTP to RWY centerline intersection

$$k = \frac{\text{RWY width}}{2}+100$$

ϕ = degree of offset

E = 0.036**D** + 392.8

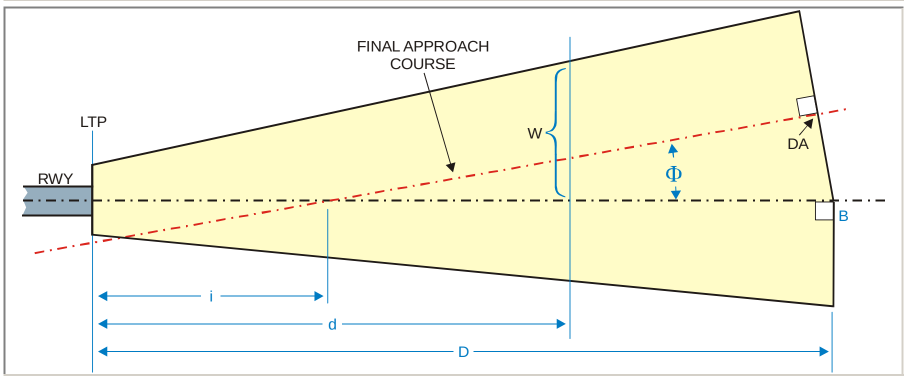
Example

d = 1,800 i = 2,100 D = 3,200 RW = 150 $\phi = 5°$

E = 508 k = 175

$$\mathbf{W_{offset}} = 1800\left(\frac{cos(5)[sin(5)(3200-1800)+508]-175}{3200-sin(5)[sin(5)(3200-1800)+508]}\right)+175 = 418.96$$

Figure 2-18. Offset Calculation Example



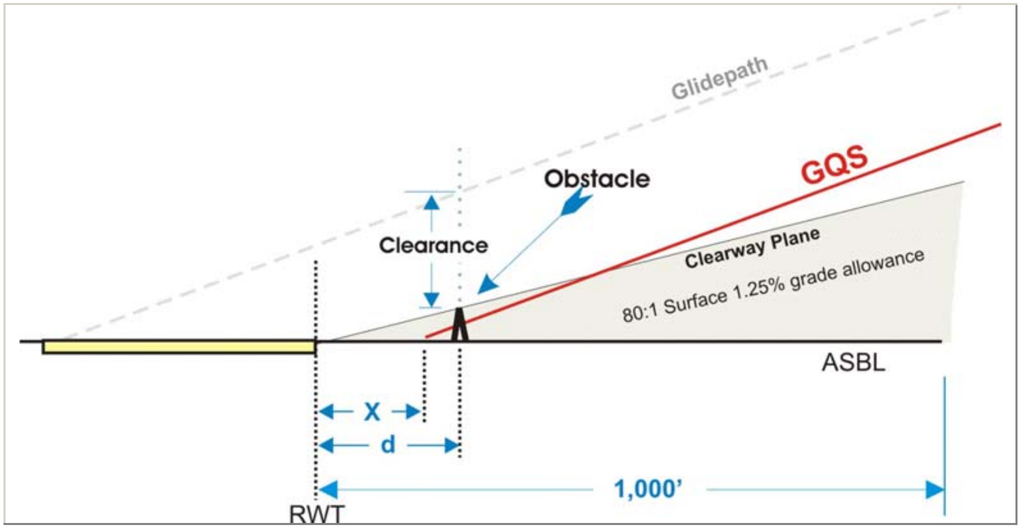
2.16.1 **d. OCS**. Obstructions must not penetrate the GQS. Calculate the height of the GQS above ASBL at any distance "**c**" measured from **RWT** along RCL extended to a point abeam the obstruction using the formula 2-16 line appropriate for the TCH value:

Formula 2-16

TCH > 50: $\mathbf{h} = \mathbf{c}\,tan\left(\frac{2\theta}{3}\right)+\mathbf{e}$
TCH $\geq$ 40 and $\leq$ 50: $\mathbf{h} = \mathbf{c}\,tan\left(\frac{2\theta}{3}\right)$
TCH < 40: $\mathbf{h} = (\mathbf{c}-\mathbf{x})\,tan\left(\frac{2\theta}{3}\right)$

2.16.1 **e. Where the TCH < 40', obstacles and terrain under the clearway plane** (1st 1,000 ft off the approach end of the runway) are not considered obstructions. The clearway plane rises from the runway threshold at a slope of 80:1 (grade of 1.25 percent) or appropriate military equivalent (see figure 2-19).

Figure 2-19. Allowable GQS Penetrations

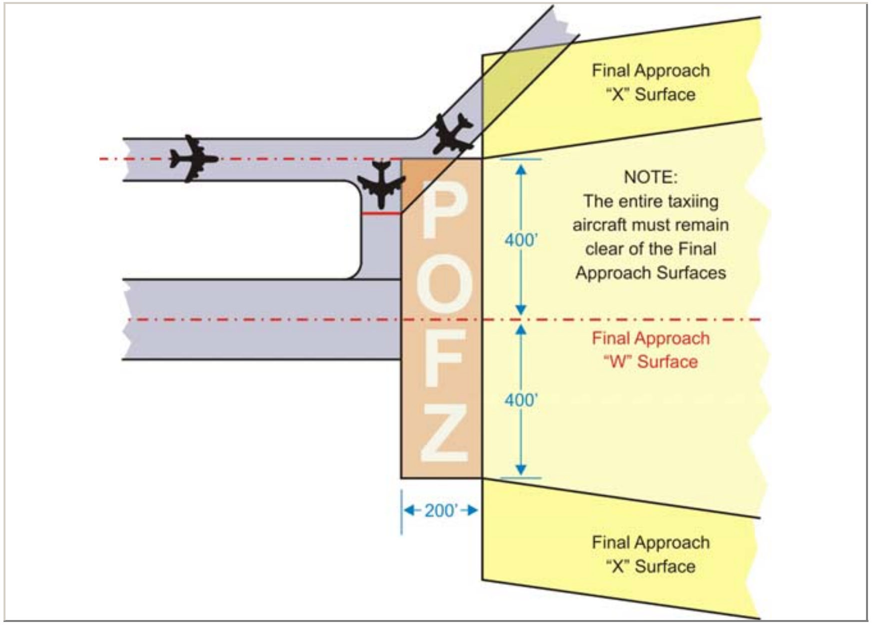


2.17 PRECISION OBSTACLE FREE ZONE (POFZ).

(*Effective when reported ceiling is less than 800 ft and/or visibility less than 2 statute miles (SM).*)

The tail and/or fuselage of a taxiing aircraft must not penetrate the POFZ when an aircraft flying a CAT I, II, or III approach reaches 2 NM from threshold. The wing of aircraft holding on a perpendicular taxiway waiting for runway clearance may penetrate the POFZ, however, the fuselage or tail must not infringe the area. The MINIMUM authorized HAT and visibility for the approach is 250 ft and ¾ SM where the POFZ is not clear (see figure 2-20).

Figure 2-20. POFZ



CHAPTER 3. LATERAL NAVIGATION (LNAV) FINAL SEGMENT

RESERVED

CHAPTER 4. LATERAL NAVIGATION WITH VERTICAL NAVIGATION (LNAV/VNAV) FINAL SEGMENT

RESERVED

CHAPTER 5. LPV FINAL APPROACH SEGMENT (FAS) EVALUATION

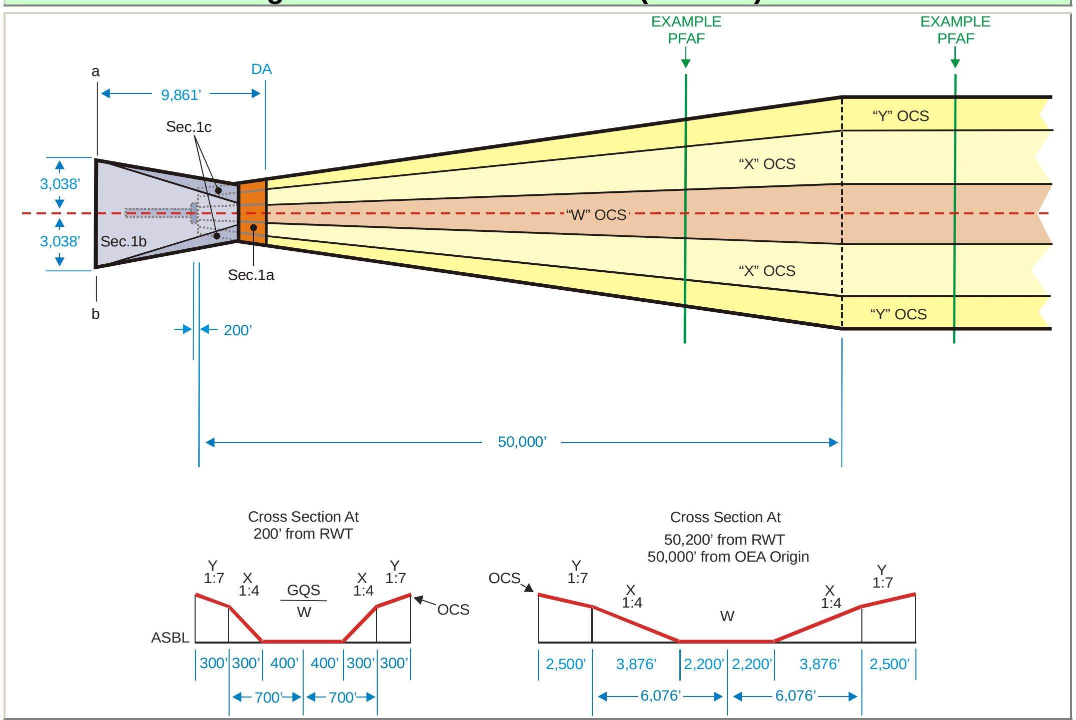
5.0 GENERAL.

The obstruction evaluation area (OEA) and associated obstacle clearance surfaces (OCSs) are applicable to LPV final approach segments. These criteria may also be applied to construction of an RNAV transition to an ILS final segment where PFAF is located within 50,200 ft from LTP.

5.1 FINAL SEGMENT OBSTRUCTION EVALUATION AREA (OEA).

The OEA originates 200 ft from LTP or FTP as appropriate, and extends to a point 131 ft (LPV FDT) beyond the PFAF. It is centered on the final approach course and expands uniformly from its origin to a point 50,000 ft from the origin where the outer boundary of the "X" surface is 6,076 ft perpendicular to the course centerline. Where the PFAF must be located more than 50,200 ft from LTP, the OEA continues linearly (boundaries parallel to course centerline) to the PFAF (see figure 5-1). The primary area OCS consists of the "W" and "X" surfaces. The "Y" surface is an early missed approach transitional surface.

Figure 5-1. LPV or ILS Final (and MA) OCS

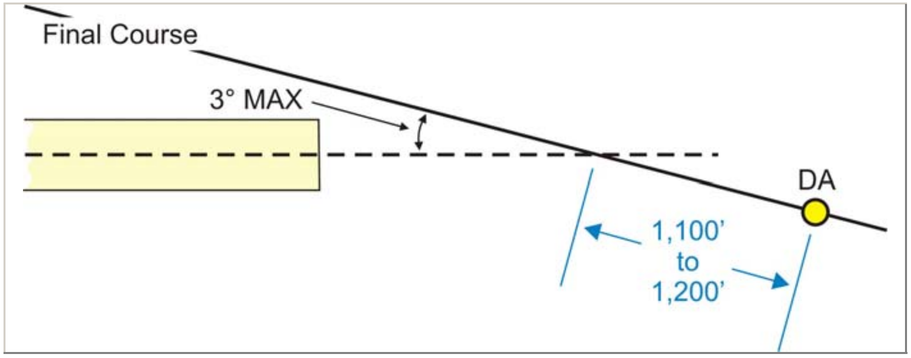


5.1.1 Alignment.

The final course is normally aligned with the runway centerline extended (± 0.03°) through the LTP (± 5 ft). Where a unique operational requirement indicates a need to offset the course from runway centerline (RCL), the offset must not exceed 3°. If the course is offset, it must intersect the RCL at a point

1,100 to 1,200 ft from the decision altitude (DA) point (see figure 5-2). Where the course is not aligned with RCL, the minimum HAT value is 250.

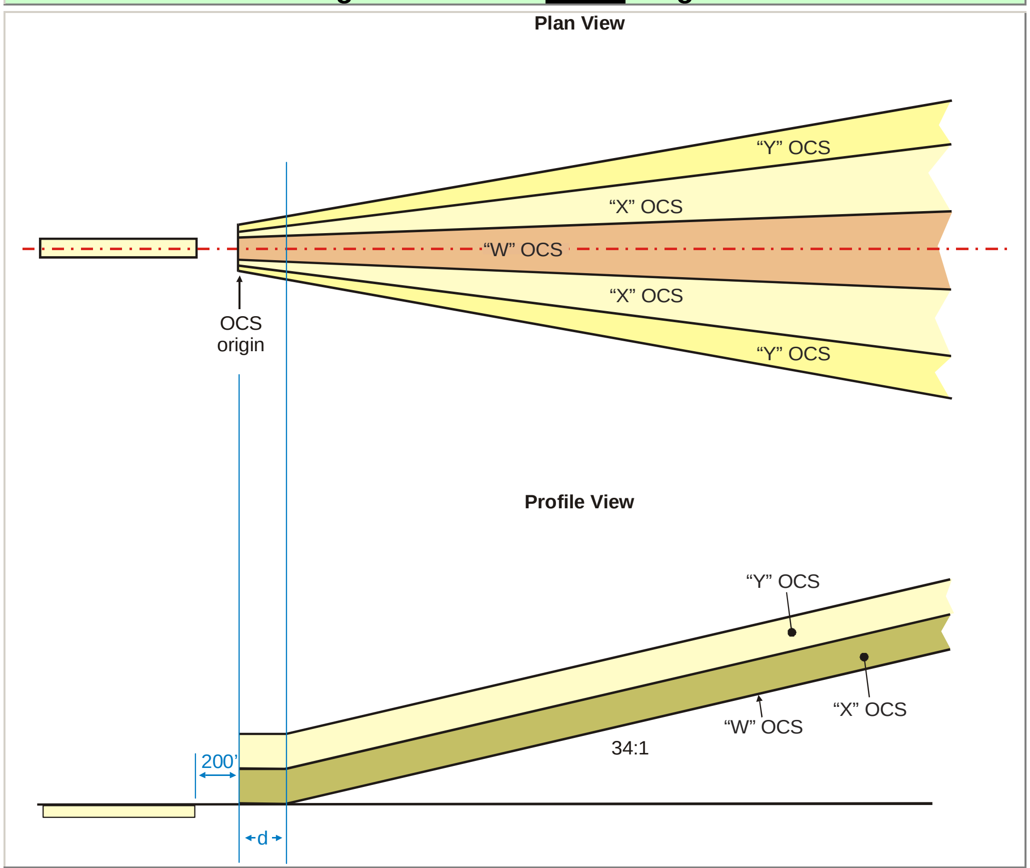
Figure 5-2. Offset Final Course



5.1.2 **OCS Slope(s)** (see figure 5-3)**.**

In this document, slopes are expressed as run over rise; e.g., 34:1. Determine the OCS slope associated with a specific glidepath angle (θ) using formula 5-1:

Figure 5-3. OCS <u>Slope</u> Origin



Formula 5-1

$$S = \frac{102}{\theta}$$

Example

$$\frac{102}{3} = 34$$

5.1.3 Origin.

The OEA originates from a point 200 ft from LTP (see figure 5-3), measured along course centerline and extends to the PFAF. The rising slope begins 200+**d** ft from OEA origin.

Where $\frac{\mathbf{TCH}}{tan(\theta)} \geq 954$, $\mathbf{d} = 0$.

Where $\frac{\mathbf{TCH}}{tan(\theta)} < 954$, calculate the value of **d** using formula 5-2.

Formula 5-2

$$\mathbf{d} = 954 - \frac{\mathbf{TCH}}{tan(\theta)}$$

Example

$$954 - \frac{44}{tan(3)} = 114.43$$

5.1.4 Obstacle Height Reduction for Earth Curvature.

Reduction of obstacle elevation to account for earth curvature is authorized in the final segment (W, X, and Y surfaces). Calculate the reduction value using formula 5-3.

Formula 5-3

$$\mathbf{reduction} = 20890537\left(\frac{1}{cos\left(\frac{\mathbf{x}}{364609}\right)} - 1\right)$$

where R is the geometric mean radius of the earth, 20,890,537 ft,

x is the obstacle distance in feet from LPT measured along the course

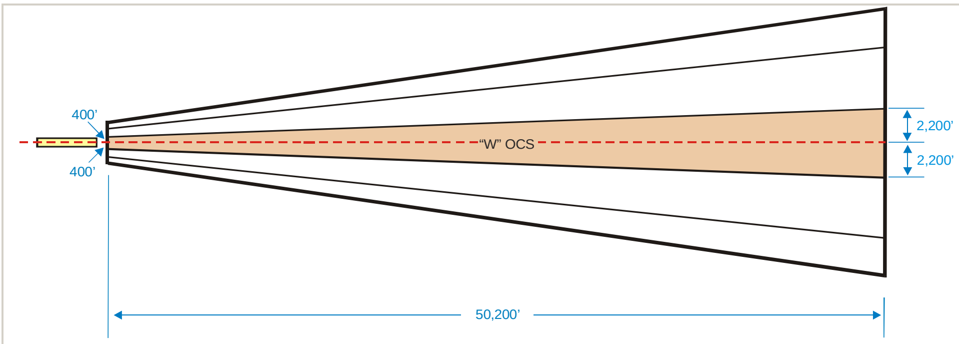
centerline, and $\frac{x}{364609}$ is the subtended central angle of the

geometric mean sphere measured in degrees

Example
x = 2.8 NM (17013.12')
$\textbf{reduction} = 20890537\left(\dfrac{1}{\cos\left(\dfrac{1701312}{364609}\right)} - 1\right) = 6.93\text{ feet}$

5.2 "W" OCS. See figure 5-4.

Figure 5-4. "W" OCS



5.2.1 Width.

The width (D_W) is 400 ft either side of the course at the origin, and expands uniformly to 2,200 ft either side of the course 50,200 ft from LTP/FTP. Calculate perpendicular distance (ft) from the course centerline to the "W" surface boundary using formula 5-4:

Formula 5-4
$D_W = 0.036D + 392.8$
where D = along course distance (ft) from LTP/FTP
Example
D = 2369
$D_W = 0.036 \times 2369 + 392.8 = 478.08$

5.2.2 Height.

Calculate the height (ft) of the "W" OCS (Z_W) above LTP elevation using formula 5-5:

Formula 5-5
$Z_W = \frac{D - 200 - d}{s}$
where D = along course distance (ft) from LTP/FTP
s = OCS slope
d = value from para 3.1.3
Example
DW = 2369 d = 0 s = 34
$D_W = \frac{2369 - 200 - 0}{34} = 63.79$

5.2.3 "W" OCS Penetrations.

Lowest minimums are achieved when the "W" surface is clear. To eliminate or avoid a penetration, take one of the following actions listed in the order of preference.

5.2.3 a. Remove or adjust the obstruction location and/or height.

5.2.3 b. Displace the RWT.

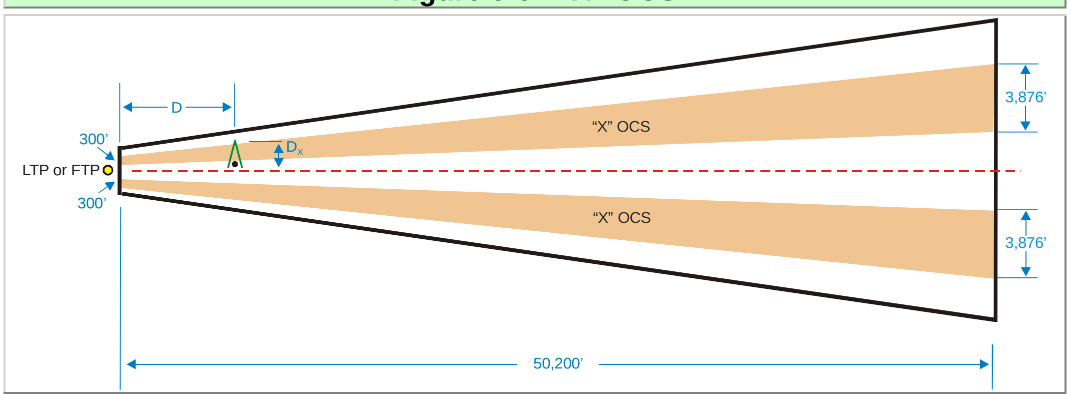
5.2.3 c. Raise the GPA (see paragraph 5.6) within the limits of table 2-5.

5.2.3 d. Adjust DA (for existing obstacles only) ($k = 0$, see paragraph 5.5.2). Minimum HAT is 250.

5.2.3 e. Raise TCH (see paragraph 5.7).

5.3 "X" OCS. See figure 5-5.

Figure 5-5. "X" OCS



5.3.1 Width.

The perpendicular distance (D_X) from the course to the outer boundary of the "X" is 700 ft at the origin. Calculate perpendicular distance (ft) from the course centerline to the “X” surface boundary using formula 5-6.

Formula 5-6

$$D_X = 0.10752D + 678.5$$

where D = along course distance (ft) from LTP/FTP

Example

D = 2369

$$0.10752 \times 2369 + 678.5 = 933.21$$

5.3.2 Height.

The "X" OCS begins at the height of the "W" surface at distance "D" from LTP or FTP, and rises at a slope of 1:4 in a direction perpendicular to the final approach course. Calculate the height of the “X” surface (**Z_X**) above LTP elevation using formula 5-7.

Formula 5-7

$$Z_X = \frac{D - 200 - d}{s} + \frac{D_O - D_W}{4}$$

where **D** = along course distance (ft) from LTP/FTP

d = "**d**" from paragraph 3.2.1, formula 3-5

D_O = perpendicular distance (ft) from course to a point in the "X" surface

D_W = perpendicular distance (ft) from course to edge of the outer "W" surface boundary

$s = \frac{102}{\theta}$

Example

D = 2369 d = 0 D_O = 933.22 D_W = 478.08 S = 34

$$\frac{2369 - 200 - 0}{34} + \frac{933.22 - 478.08}{4} = 177.58$$

5.3.3 “X" OCS Penetrations.

Lowest minimums can be achieved when the "X" OCS is clear. To eliminate, avoid, or mitigate a penetration, take one of the following actions listed in the order of preference.

5.3.3 **a. Remove or adjust the obstruction location and/or height.**

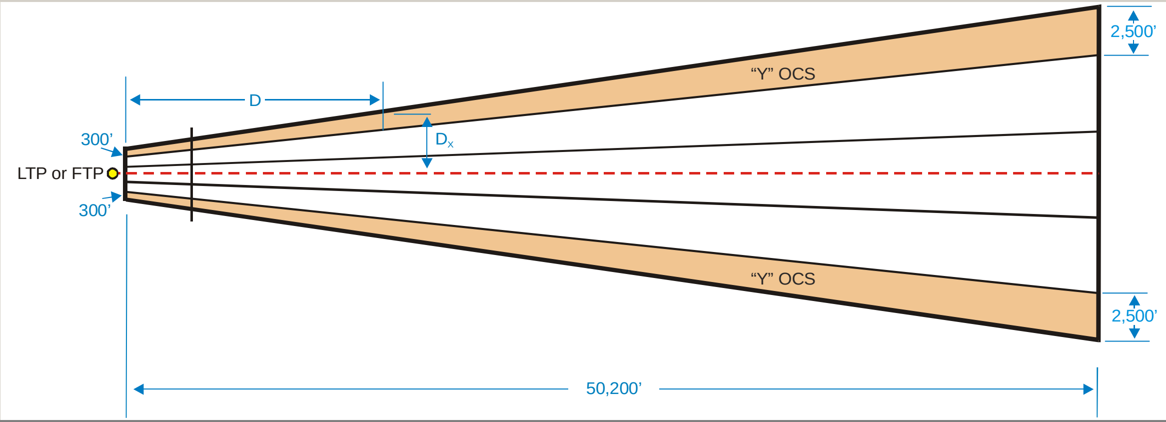
5.3.3 **b. Displace the RWT.**

5.3.3 **c. Raise the GPA** (see paragraph 5.6) within the limits of table 2-5.

5.3.3 **d. Adjust DA** (for existing obstacles only) ($k = Z_X - Z_W$, see paragraph 5.5.2). Minimum HAT is 250.

5.4 "Y" OCS. See figure 5-6.

Figure 5-6. “Y” Surface



5.4.1 Width.

Calculate perpendicular distance (ft) from the course centerline to the “Y” surface boundary using formula 5-8.

Formula 5-8

$$\mathbf{D_Y} = 015152\mathbf{D} + 969.7$$

where **D** = along course distance (ft) from LTP/FTP

Example

D = 2369

$$\mathbf{D_Y} = 015152 \times 2369 + 969.7 = 1328.65$$

5.4.2 Height.

The “Y” OCS begins at the height of the “X” surface at distance “D” from LTP or FTP, and rises at a slope of 7:1 in a direction perpendicular to the final approach course. Calculate the height of the “Y” surface (Z_Y) above LTP elevation using formula 5-9:

Formula 5-9

"W" Sfc "X" Sfc "Y" Sfc

$$Z_Y = \frac{D-(200+d)}{S} + \frac{\mathbf{D_x} - \mathbf{D_w}}{4} + \frac{\mathbf{D_o} - \mathbf{D_x}}{7}$$

Where D = the distance in feet from the LTP or FTP,

d = d from paragraph 3.1.3

Dx = the perpendicular distance in feet between course centerline and "X" surface outer boundary,

D0 = perpendicular distance in feet between course centerline and an obstruction in the "Y" surface.

Example
d = 0 D = 2369 Dx = 933.21 Dw = 478.08 Do = 933.21 S = 34
$D_Y = \frac{D\text{-}200\text{-}d}{S} + \frac{D_x - D_w}{4} + \frac{D_o - D_x}{7} = 177.59$

5.4.3 "Y" OCS Penetrations.

Lowest minimums can be achieved when the "Y" surface is clear. When the surface is penetrated, remove the obstruction or reduce its height to clear the surface. If this is not possible, a subjective evaluation is necessary. Consider the obstruction's physical nature, the amount of penetration, obstruction location with respect to the "X" surface boundary, and density of the obstruction environment to determine if the procedure requires adjustment. (**USAF**: Adjustment mandatory if obstruction cannot be removed, height adjust, or options in paragraphs 5.4.3 b-d cannot be accomplished.) If an adjustment is required, take the appropriate actions from the following list:

5.4.3 a. Displace threshold.

5.4.3 b. Offset final course.

5.4.3 c. Raise GPA (see paragraph 5.6).

5.4.3 d. Adjust DA for existing obstacles ($k = Z_Y - Z_W$, see paragraph 5.5.2).

5.4.3 e. If an adjustment is not required, CHART the obstruction.

5.5 HAT AND DA.

The DA value may be derived from the HAT. The MINIMUM HAT for LPV operations is the greater of 200 ft or the value derived from table 2-5. If the OCS is penetrated, minimum HAT is 250. Round the DA result to the next higher whole number.

5.5.1 DA Calculation (Clear OCS).

Where the OCS is clear, calculate the DA using formula 5-10.

Formula 5-10

$$\mathbf{DA} = \mathbf{HAT} + \mathbf{TDZE}$$

where TDZE = touchdown zone elevation

Examples

TDZE = 1123

$$\mathbf{DA} = 259 + 1123 = 1382$$

Calculate the along-course distance in feet from DA to LTP/FTP ($\mathbf{X_{DA}}$) using formula 5-11.

Formula 5-11

$$X_{DA} = \frac{\mathbf{HAT} - \mathbf{TCH} - \left(\mathbf{TDZE} - \mathbf{LTP_{elevation}}\right)}{tan(\theta)}$$

Example

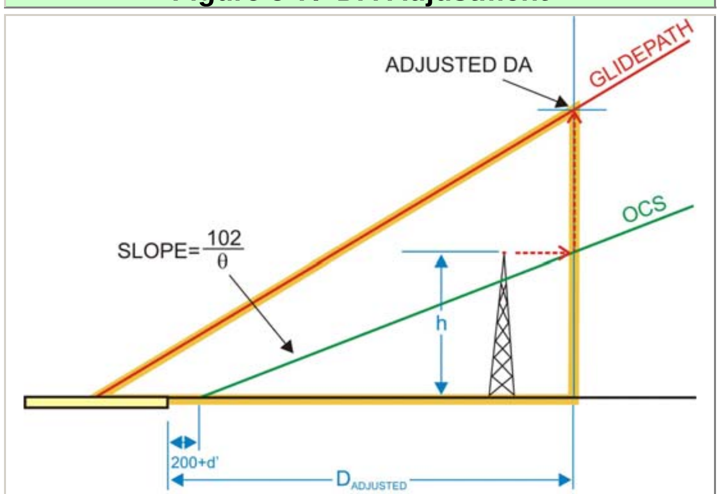
HAT = 259 TCH = 50 $LTP_{elevation}$ = 1123

TDZE = 1124 θ = 3.1°

$$X_{DA} = \frac{259 - 50 - (1124 - 1123)}{tan\left(31\cdot\frac{314...}{180}\right)} = 3840.61$$

5.5.2 DA Calculation (OCS Penetration). See figure 5-7.

Figure 5-7. DA Adjustment



Calculate the along course distance in feet from the adjusted DA ($\mathbf{X_{DAadjusted}}$) to LTP/FTP using formula 5-12.

Formula 5-12
$$X_{DAadjusted}=\frac{102(\mathbf{h}-\mathbf{k})}{\theta}+200+\mathbf{d}$$
where h = obstacle height above ASBL
d = "d" from paragraph 3.2.1, formula 3-5
k = value from para 3.2.3d, 3.3.3d, or 3.4.3d as appropriate
Example
h = 163 d =0 θ = 3.1° k = 0
$$X_{DAadjusted}=\frac{102(163-0)}{31}+200+0=5563.23$$

5.5.3 **Calculate the $HAT_{adjusted}$** for **$D_{adjusted}$** using formula 5-13, round result to the next higher foot value.

Formula 5-13
$$HAT_{adjusted}=tan(\theta)\times D_{adjusted}+TCH-(TDZE-LTP_{elevation})$$
Example
θ = 3.1° $D_{adjusted}$ = 5563.23 TDZE = 1124
$LTP_{elevation}$ = 1123 TCH = 50
$$HATadjusted=tan\left(31\cdot\frac{314...}{180}\right)\times5563.23+50-(1124-1123)=350.29$$
round to 351

If the HAT value from formula 5-13 is equal to or less than the **minimum HAT** from paragraph 5.5, apply paragraph 5.5.1 as if the OCS was clear.

If **$HAT_{adjusted}$** is greater than the **minimum HAT**, calculate the adjusted DA (**$DA_{adjusted}$**) using formula 5-14.

Formula 5-14
$$DA_{adjusted}=HAT_{adjusted}+TDZE$$
Examples
$$DA_{adjusted}=351+1124=1475$$

5.6 REVISING GLIDEPATH ANGLE (GPA) FOR OCS PENETRATIONS.

Raising the GPA may eliminate OCS penetrations. To determine the revised minimum GPA, use formula 5-15.

Formula 5-15

$$\text{Revised Angle} = \frac{102}{\mathbf{s}}\left(1+\frac{\mathbf{ps}}{\mathbf{D}-200-\mathbf{d}}\right)$$

where D = distance (ft) from LTP

d = d from paragraph 9a

$$s = \frac{102}{\theta}$$

p = penetration in feet

Example

D = 2200 d = 0 s = 32.9 p = 2.8

$$\frac{102}{32.9}\left(1+\frac{2.8\times 32.9}{2200-200-0}\right) = 3.25° \ *$$

**Actual answer is 3.243°. Always round to the next higher hundredth (0.01) degree. This prevents rounding errors in amount of penetration causing miniscule penetration values using the revised angle.*

5.7 ADJUSTING TCH TO REDUCE / ELIMINATE OCS PENETRATIONS.

This paragraph is applicable <u>ONLY</u> where **d** from paragraph 5.1.3, formula 5-2, is greater than zero. Adjusting TCH is the equivalent to relocating the glide slope antenna in ILS criteria. The goal is to move the OCS origin toward the LTP/FTP (no closer than 200 ft) sufficiently to raise the OCS at the obstacle location. To determine the maximum "**W**" surface vertical relief (**z**) that can be achieved by adjusting TCH, apply formula 5-16. If the value of **z** is greater than the penetration (**p**), you may determine the amount to increase TCH by applying formula 5-17. If this option is selected, re-evaluate the final segment using the revised TCH value.

Formula 5-16

$$z = \frac{\mathbf{d\theta}}{102}$$

where d = "d" from paragraph 5.1.3, formula 5-2

θ = glidepath angle

Example

d = 114.43 θ = 3.1°

$$\frac{114.43\times 31}{102} = 3.48$$

Formula 5-17

$$TCH_{adjustment} = tan(\theta) \times \left(\frac{102\mathbf{p}}{\theta}\right)$$

where p = penetration (ft) ($p \leq z$)

θ = glidepath angle

Example

p = 3.30 θ = 3.1°

$$TCH_{adjustment} = tan(31) \times \left(\frac{102 \times 3.30}{31}\right) = 5.88$$

CHAPTER 6. MISSED APPROACHES

6.0 MISSED APPROACH SECTION 1 (Height Loss and Initial Climb).

The missed approach segment begins at decision altitude (DA) and ends at the clearance limit. It is comprised of section 1 (height loss and initial climb) and section 2 (from end of section 1 to the clearance limit). Obstacle protection is based on an assumed minimum climb gradient of 200 ft/NM (30.38:1 slope). Section 1 is centered on a continuation of the final approach track and is subdivided into sections 1a and 1b (see figures 6-1A and B).

Figure 6-1A. Section 1 3D Perspective

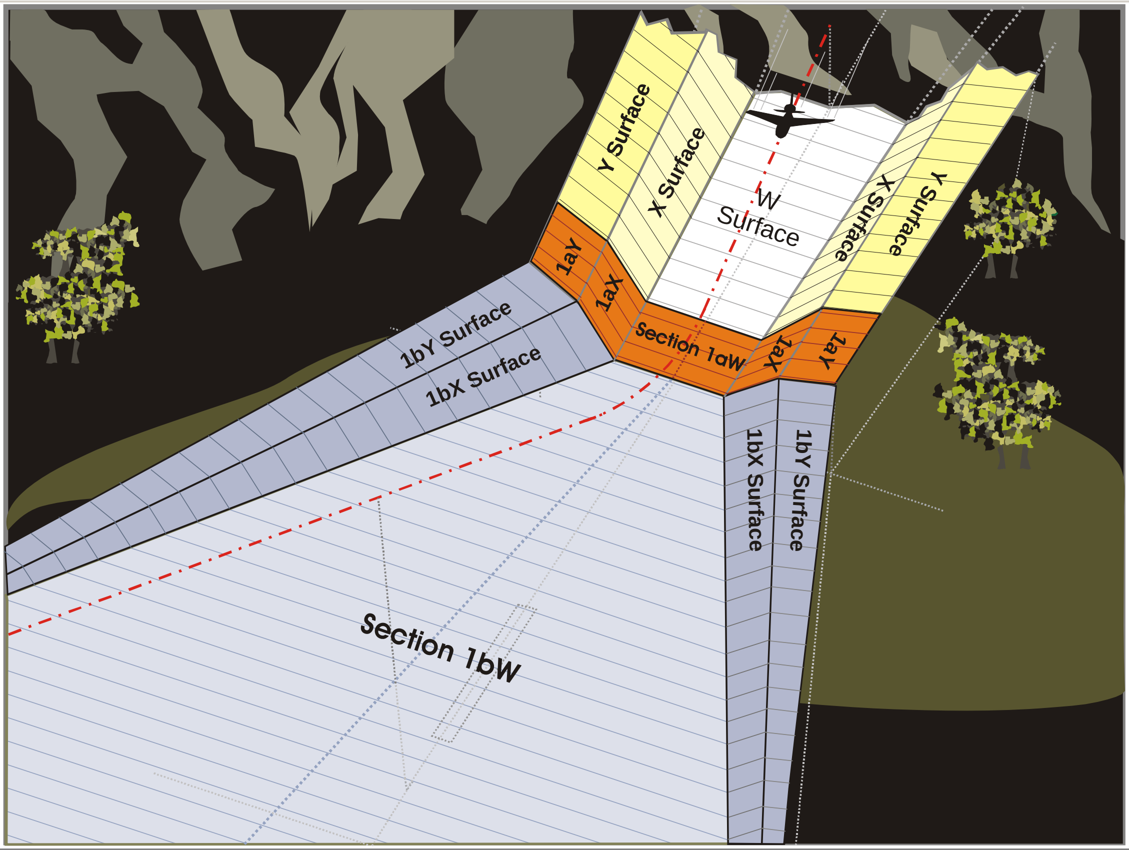
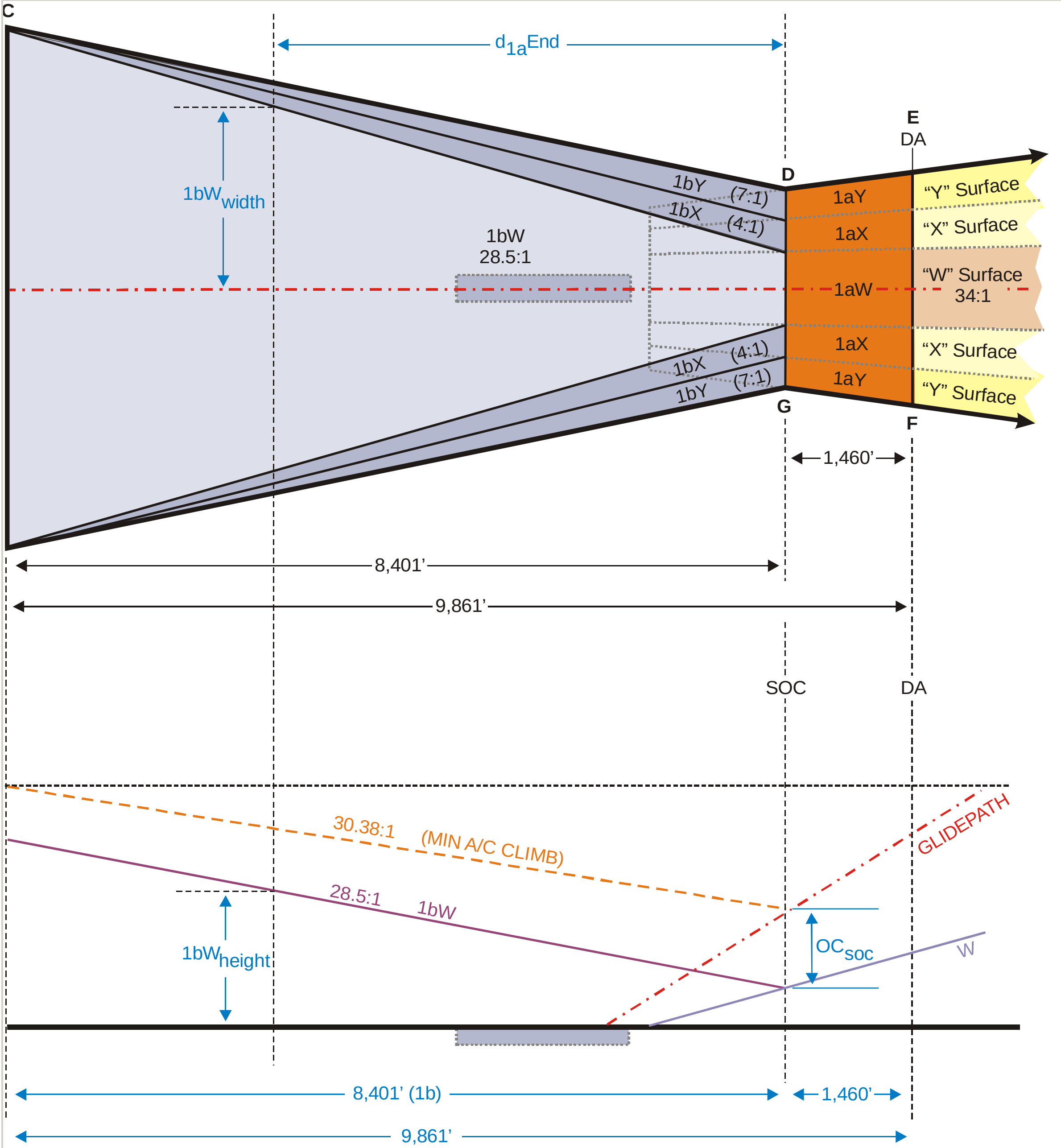


Figure 6-1B. Section 1 (a/b) 2D Perspective



6.1 SECTION 1a.

Section 1a is a 1,460 ft continuation of the FAS OCS beginning at the DA point to accommodate height loss. The portion consisting of the continuation of the **W** surface is identified as section **1aW**. The portions consisting of the continuation of the **X** surfaces are identified as section **1aX**. The portions consisting of the continuation of the **Y** surfaces are identified as section **1aY**. The maximum height loss (**hl**) value accommodated by section 1a can be calculated using formula 6-1.

Formula 6-1

$$\mathbf{hl} = tan(\theta) \times 1460$$

Example

$\theta = 3.1°$

$$\mathbf{hl} = tan(3.1) \times 1460 = 79.07$$

The MSL elevation of the glidepath (**$GP_{@1Aend}$**) at the end of section 1A is calculated using formula 6-2.

Formula 6-2

$$\mathbf{GP_{@1Aend}} = \mathbf{DA} - \mathbf{hl}$$

Example

Where DA = 1383 hl = 79.07

$$\mathbf{GP_{@1Aend}} = 1383 - 79.07 = 1303.93$$

The end of section 1a is considered the start-of-climb (**SOC**) point. The obstacle clearance at the start of climb point (**OC_{SOC}**) is the difference between the glidepath altitude at SOC and the height of the section 1aW surface at SOC.

NOTE: OC_{SOC} is used in the turn initiation area for a climb-to-altitude based on the initial MA segment in paragraph 6.5.3.

Calculate the elevation of the end of the **1aW** surface using formula 6-3.

Formula 6-3

$$1\mathbf{A_{end}} = \frac{\theta(\mathbf{X_{DA}} - \mathbf{d} - 1660)}{102} + \mathbf{LTP_{elev}}$$

where X_{DA} = along-track distance from LTP to DA

d = value from paragraph 5.1.3

Example

$LTP_{elev} = 1123$ d = 0 $X_{DA} = 3785.22$ $\theta = 3.1°$

$$1\mathbf{A_{end}} = \frac{3.1(3785.22 - 0 - 1660)}{102} + 1123 = 1187.59$$

Calculate the width and elevation of the section **1aW**, **1aX**, and **1aY** surfaces at any distance from LTP using the final segment formulas.

6.2 SECTION 1b.

The section 1b surface extends 8,401 ft from end of section 1A as an up-sloping surface. Section 1b is subdivided into sections **1bW**, **1bX**, and **1bY** (see figure 6-1B).

6.2.1 Section 1bW.

Section **1bW** extends from the end of section **1aW** for a distance of 8,401 ft. Its lateral boundaries splay from the width of the end of the **1aW** surface to a width of ± 3,038 ft either side of the missed approach course at the 8,401 ft point. Calculate the width of the **1bW** surface at any distance "**d_{1aEnd}**" from the end of section **1a** using formula 6-4.

Formula 6-4

$$1bW_{width} = \frac{d_{1aEnd}(3038 - C_W)}{8401} + C_W$$

where d_{1aEnd} = along-track distance (ft) from end of section 1a

C_W = half-width of 1aW surface at section 1a end

Example

$d_{1aEnd} = 3100 \quad C_W = 530.18$

$$1bW_{width} = \frac{3100(3038 - 53018)}{8401} + 53018 = 1455.57$$

The surface rises from the height of the **1aW** surface at the end of section 1a at a slope ratio of 28.5:1. Calculate the height of the surface using formula 6-5.

Formula 6-5

$$1bW_{height} = 1a_{end} + \frac{d_{1aEnd}}{28.5}$$

where d_{1aEnd} = along-track distance (ft) from end of section 1A

Example

where $d_{1aEnd} = 3100 \quad 1A_{end} = 1187.59$

$$1bW_{height} = 1187.59 + \frac{3100}{28.5} = 1198.47$$

6.2.2 Section 1bX.

Section **1bX** extends from the end of section **1aX** for a distance of 8,401 ft. Its inner boundary is the outer boundary of the **1bW** surface. Its outer boundary splays from the end of the **1aX** surface to a width of ± 3,038 ft either side of the missed approach course at the 8,401 ft point. Calculate the distance from the missed approach course centerline to the surface outer boundary using formula 6-6.

Formula 6-6

$$1bX_{width} = \frac{d_{1aEnd}(3038 - C_X)}{8401} + C_X$$

where d_{1aEnd} = along-track distance from end of section 1A

C_X = perpendicular distance (ft) from course centerline to 1aX outer edge at section 1a end

Example

$d_{1aEnd} = 3100 \quad C_X = 1088.80$

$$1bX_{width} = \frac{3100(3038 - 1088.80)}{8401} + 1088.80 = 1808.06$$

The surface rises at a slope ratio of 4:1 perpendicular to the missed approach course from the edge of the **1bW** surface. Calculate the height of the **1bX** missed approach surface using formula 6-7.

Formula 6-7

$$1bX_{height} = 1bW_{height} + \frac{a - 1bW_{width}}{4}$$

where a = the perpendicular distance (ft) from the missed approach course

Example

$1bW_{height} = 1296.36 \quad 1bW_{width} = 1455.57 \quad a = 1783$

$$1bX_{height} = 1296.36 + \frac{1783 - 1455.57}{4} = 1378.22$$

6.2.3 Section 1bY.

Section **1bY** extends from the end of section **1aY** for a distance of 8,401 ft. Its inner boundary is the outer boundary of the **1bX** surface. Its outer boundary splays from the outer edge of the **1aY** at the surface at the end of section **1a** to a width of ± 3,038 ft either side of the missed approach course at the 8,401 ft point. Calculate the distance from the missed approach course centerline to the surface outer boundary using formula 6-8.

Formula 6-8

$$1bY_{width} = \frac{d_{1aEnd}(3038 - C_Y)}{8401} + C_Y$$

where d_{1aEnd} = along-track distance from end of section 1A

C_Y = perpendicular distance (ft) from course centerline to the 1aY outer edge at section 1a end

Example

$d_{1aEnd} = 3100 \quad C_Y = 1547.90$

$$1bY_{width} = \frac{3100(3038 - 1547.90)}{8401} + 1547.90 = 2097.75$$

The surface rises at a slope ratio of 7:1 perpendicular to the missed approach course from the edge of the **1bX** surface. Calculate the height of the **1bY** missed approach surface using formula 6-9.

Formula 6-9

$$1bY_{height} = 1bX_{height} + \frac{a - 1bX_{width}}{7}$$

where a = the perpendicular distance (ft) from the missed approach course

Example

$1bX_{height} = 1378.22 \quad a = 1917.03 \quad 1bX_{width} = 1808.06$

$$1bY_{height} = 1378.22 + \frac{1917.03 - 1808.06}{7} = 1393.79$$

6.3 SURFACE HEIGHT EVALUATION.

6.3.1 Section 1a.

Obstacles that penetrate these surfaces are mitigated during the final segment OCS evaluation. However in the missed approach segment, penetrations are not allowed; therefore, penetrations must be mitigated by:

- Raising TCH (if GPI is less than 954 ft).
- Removing or reducing obstruction height.
- Raising glidepath angle.
- Adjusting DA.

6.4 DA Adjustment for a Penetration of Section 1B Surface.

The DA is adjusted (raised and consequently moved further away from LTP) by the amount necessary to raise the 1b surface above the penetration. For a 1b surface penetration of **p** ft, the DA point must move ΔX_{DA} feet farther from the LTP determined by formula 6-10.

Formula 6-10

$$\Delta X_{DA} = \frac{2907\mathbf{p}}{28.5\theta + 102}$$

simplified from $\dfrac{p}{\left(\dfrac{1}{28.5} + \dfrac{\theta}{102}\right)}$

Example

$p = 20 \quad \theta = 3.1$

$$\Delta X_{DA} = \frac{2907 \times 20}{28.5 \times 31 + 102} = 305.44 \text{ ft}$$

This increase in the DA to LTP distance raises the DA (and HAT). Calculate the adjusted DA using formula 6-11. Round the result up to the next 1-foot increment.

Formula 6-11

$$DA_{adjusted} = tan(\theta)(X_{DA} + \Delta X_{DA}) + LTP_{elev} + TCH$$

where θ = glidepath angle

Example

$\theta = 3.1° \quad X_{DA} = 3877.54 \quad \Delta X_{DA} = 305.44 \quad LTP_{elev} = 1123 \quad TCH = 50$

$$DA_{adjusted} = tan(31)(3877.54 + 305.44) + 1123 + 50 = 1399.54$$

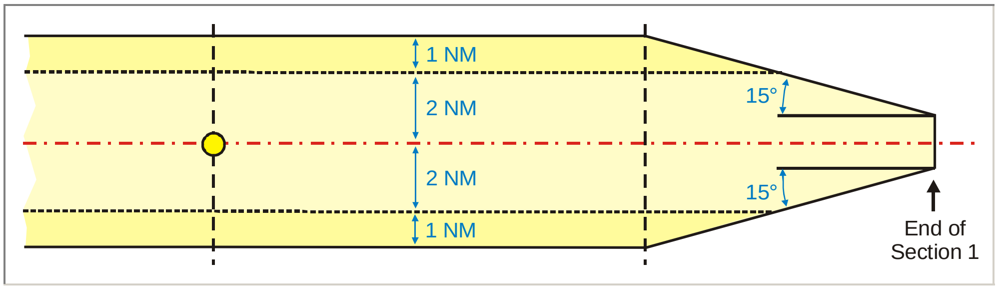
round to 1400

6.5 MISSED APPROACH SECTION 2.

6.5.1 Straight Missed Approach.

The OEA for straight-ahead legs expand at a rate of 15° until reaching the ± 2 NM for primary and 1 NM for secondary areas (see figure 6-2). The 40:1 OCS continues from the end of section 1A.

Figure 6-2. Straight Missed Approach (Legs with Specified Tracks)



6.5.2 Turning Missed Approach.

Turning criteria applies when the course differs from the final approach course by more than .03°. There are two turn constructions: turn at an altitude and turn at a fix. Track guidance is assumed throughout the operation; therefore, turns to intercept a course and dead reckoning (DR) segments are not considered.

6.5.2 a. **Obstacle Clearance (OC).** The OEA begins at the end of section 1B and expands at 15° relative to course (see figure 6-3). The OCS rises at a slope of 40:1.

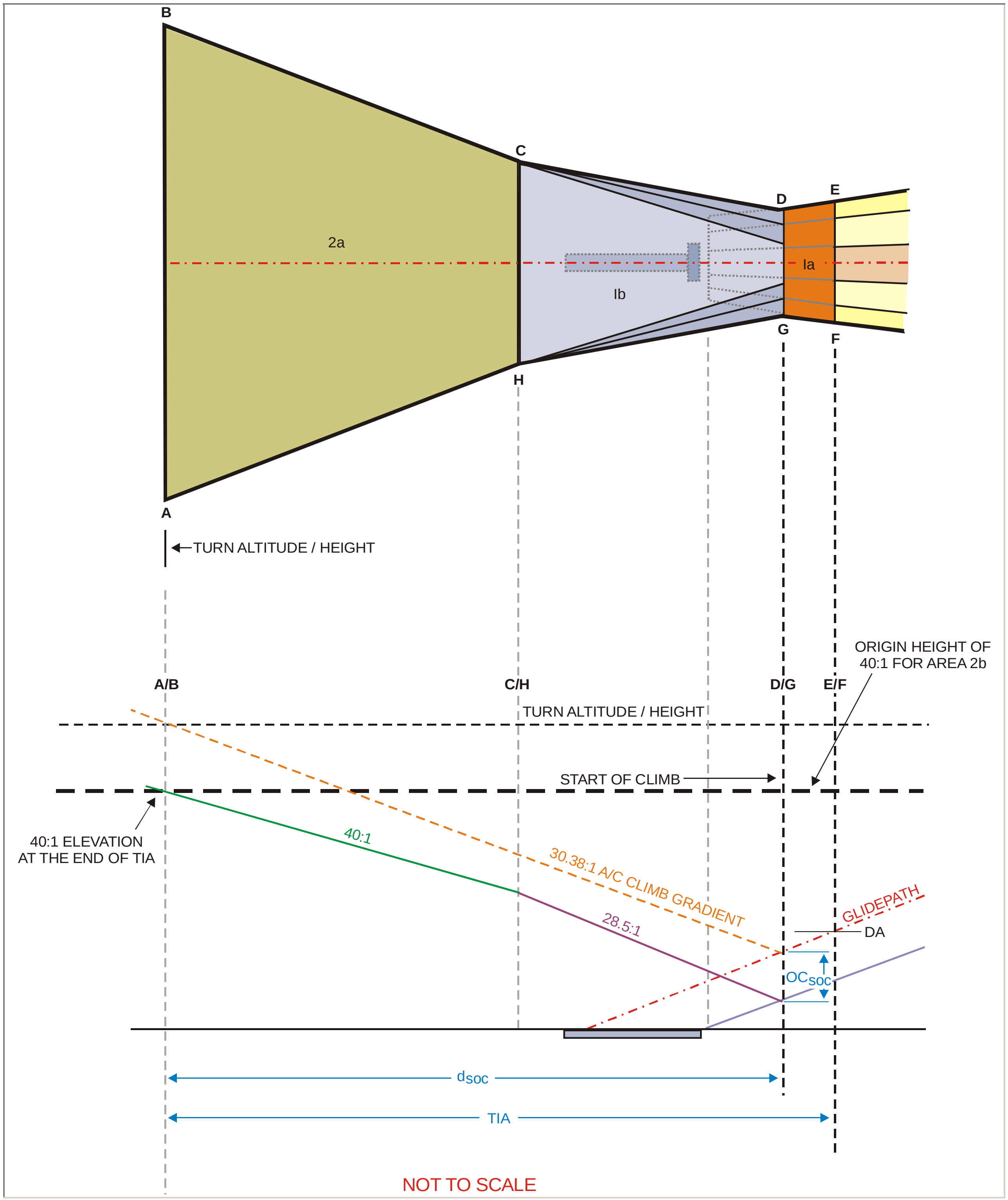
6.5.2 b. **Climb Gradient.** The assumed aircraft minimum climb path gradient is 30.38:1 (200 ft/NM) beginning at the end of section 1A. This point is designated as the start-of-climb (SOC).

6.5.3 Turns at an Altitude.

6.5.3 a. **Turn Initiation Area (TIA)**. Construct a TIA based on the earliest and latest turn points. The earliest turn point is coincident with the DA point. The latest turn point is where the aircraft reaches the specified turn altitude. The specified turn altitude must be equal to or higher than the altitude reached at the end of section 1B. The lateral boundaries of the TIA are the outer boundaries of section 1 from the DA point to the end of the TIA.

The 40:1 for area 2b begins at the boundary of the TIA at the height of the 40:1 at the end of area 2a on centerline.

Figure 6-3. Missed Approach: - Straight Segment



The OCS for the area following the turn begins at the boundary of the TIA along lines A-B-C-D (or A-B-C) at the elevation of the OCS at the end of the TIA. Apply the 40:1 OCS to all obstacles after the turn based on the shortest distance (**do**) from the boundary of the TIA to the obstacle. See figures 6-4, 6-5, 6-6, and 6-7.

Figure 6-4. Turn at Altitude – Direct to Waypoint Small Angle Turn

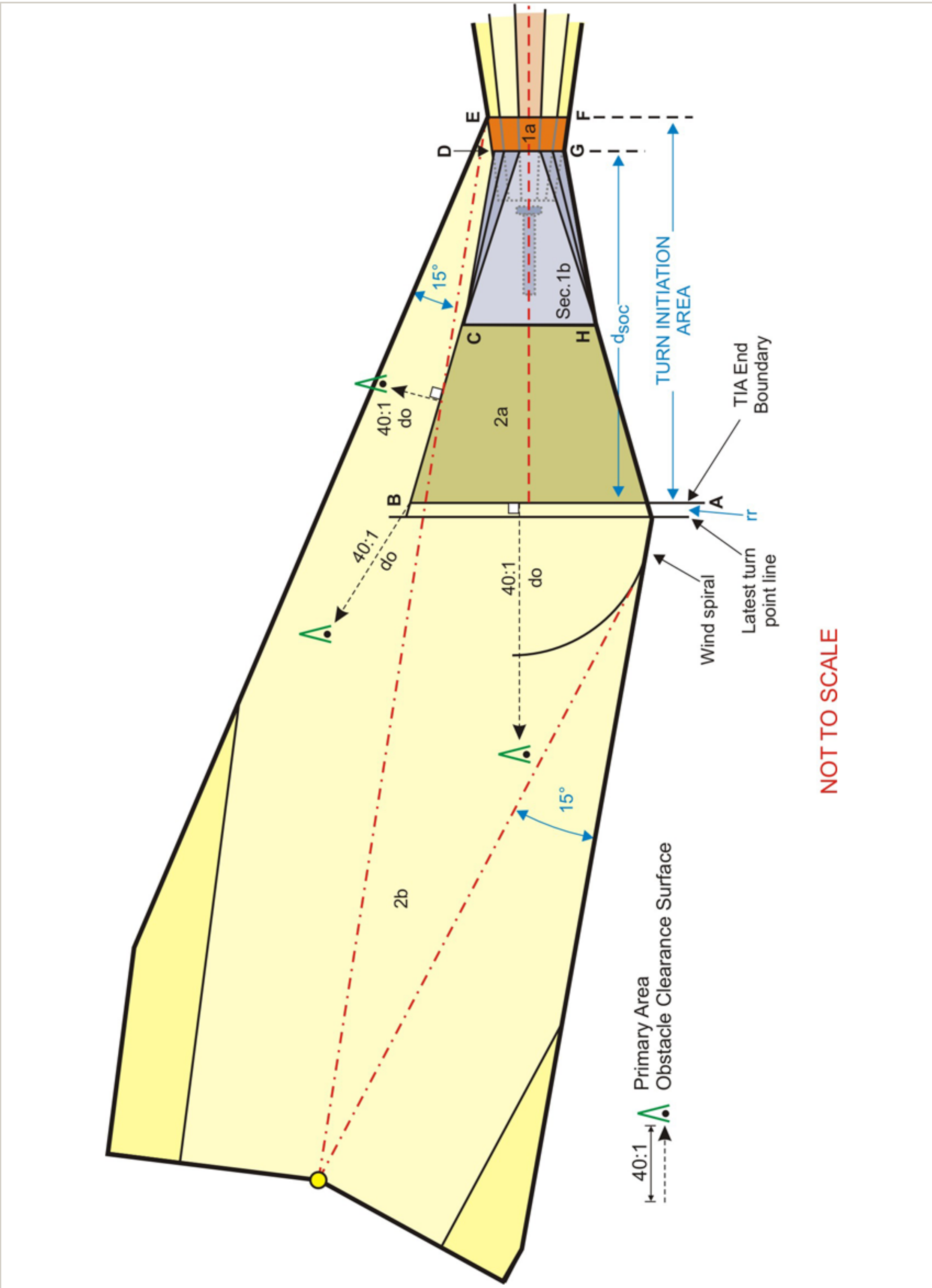


Figure 6-5. Turn at Altitude.
TIA must Extend to the End of Section 1B.

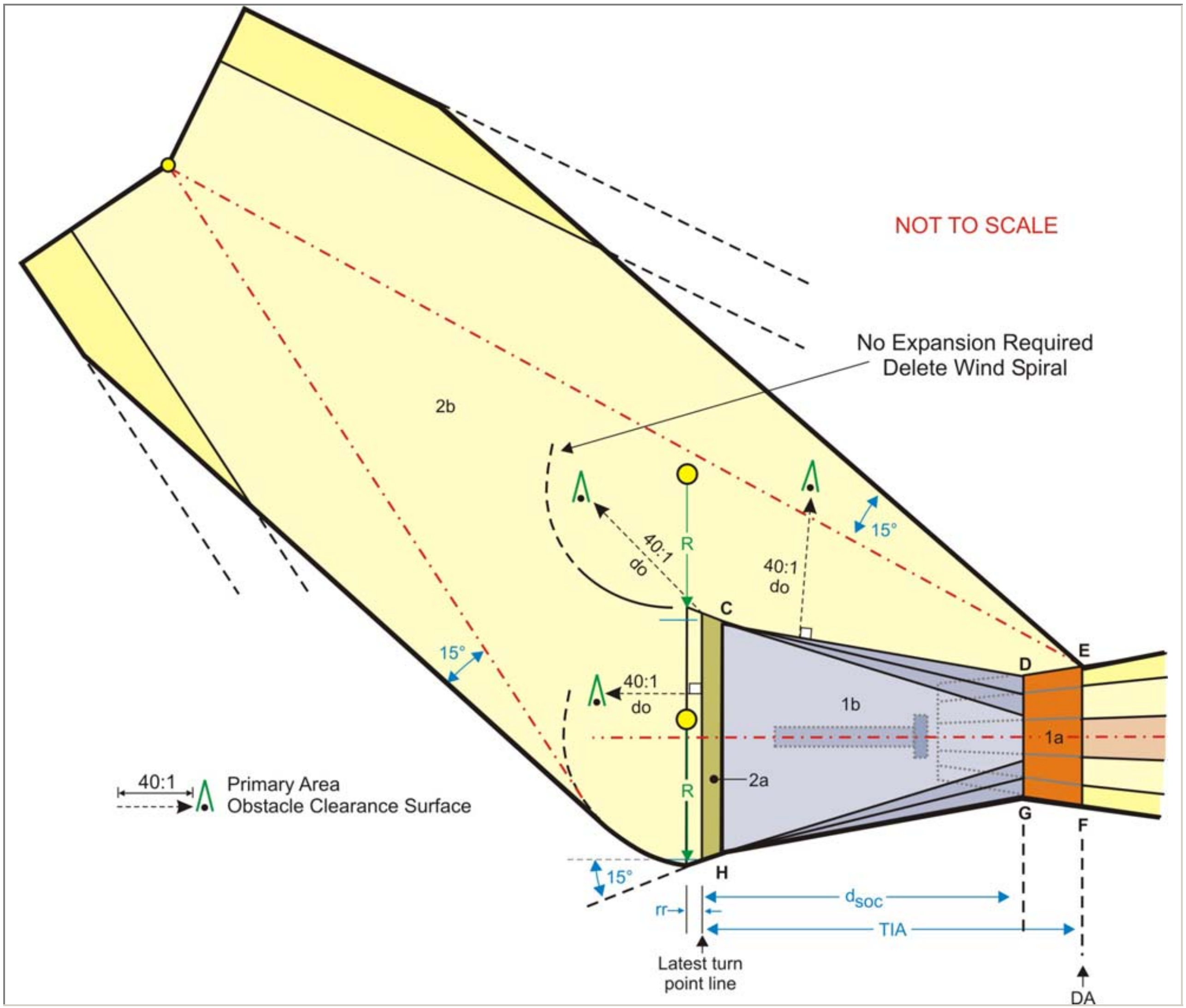


Figure 6-6. Turn at Altitude (Minimum Straight Segment)

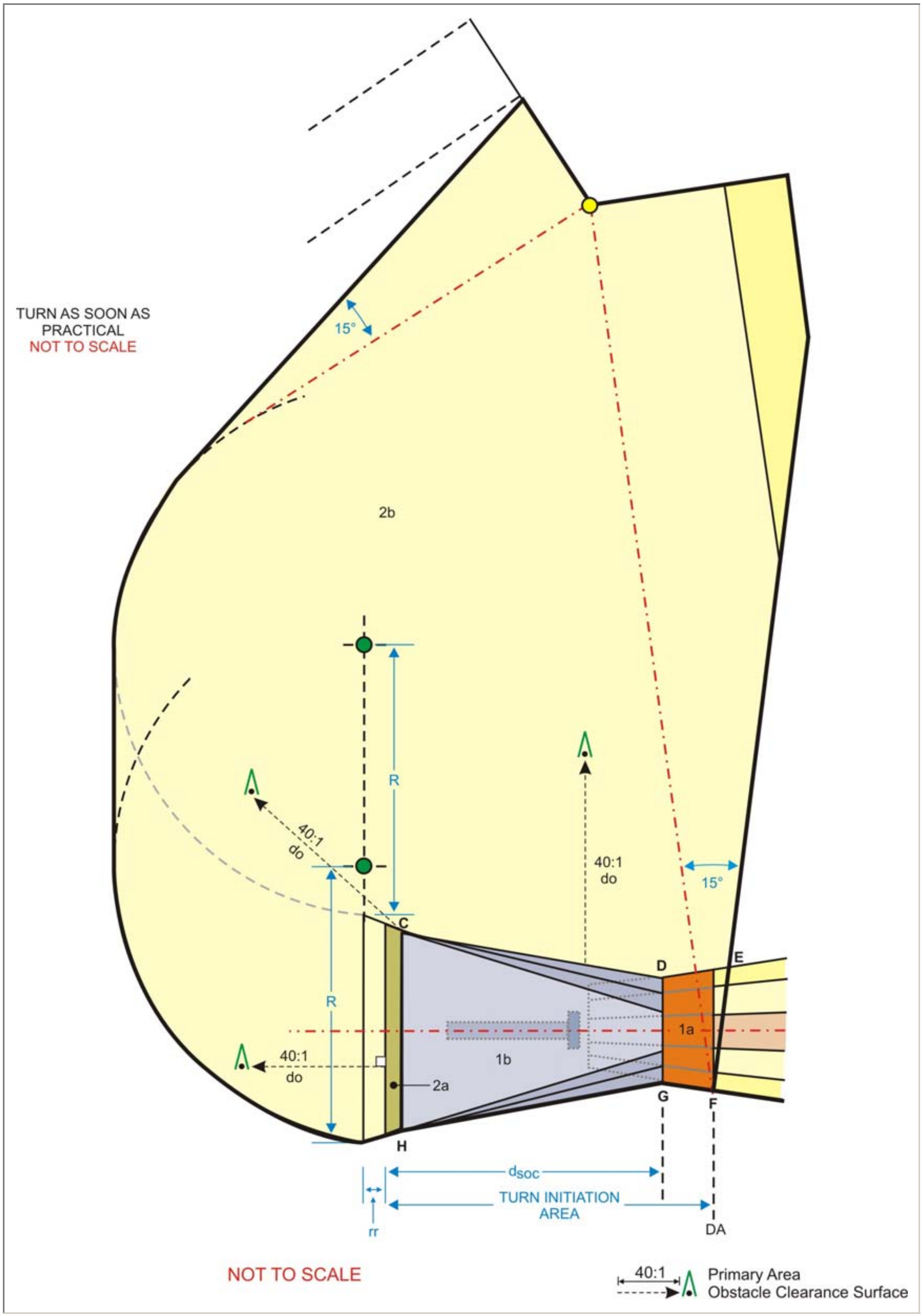
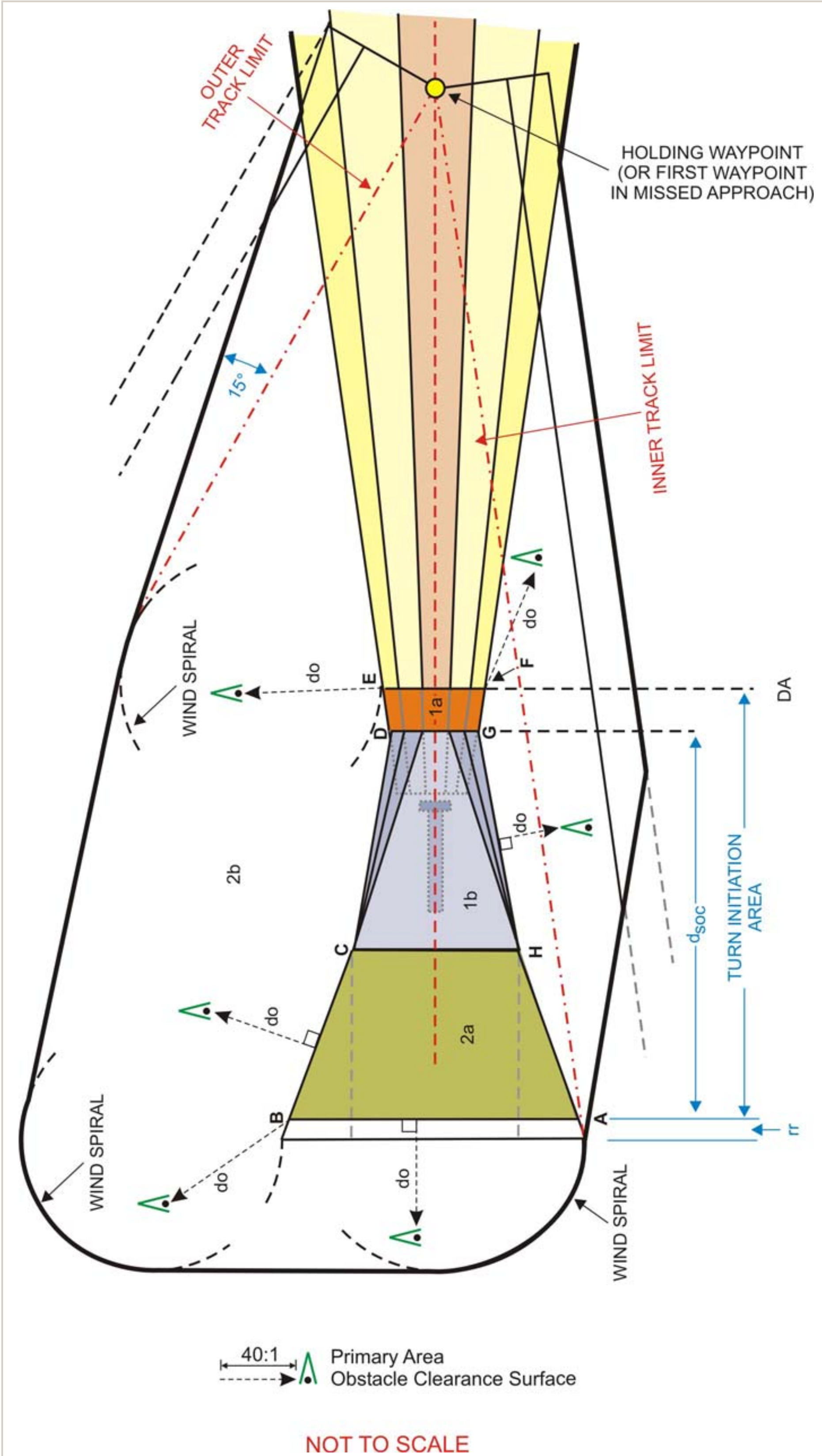


Figure 6-7. Turn at Altitude ≥ 180°



A direct-to-fix (DF) leg must follow a turn at an altitude construction. Locate the latest turn point at the distance from SOC where the turn altitude is reached plus a reaction/roll-in additive of (**rr**) feet. Calculate **rr** using formula 6-12.

Formula 6-12
$\mathbf{rr} = 1013 \times \mathbf{V_{KTAS}}$
Example
Considering Category D @ 265 KIAS at 3100 feet
$\mathbf{rr} = 1013 \times 281.43 = 2850.89$

6.5.3 **b. Construction of the OEA after the Turn.** A DF leg must immediately follow a turn at altitude. The OEA is defined by airspace protecting the earliest and latest direct tracks from the TIA to the fix. Construct the obstacle areas about each of the tracks as described below. Various turn geometry constructions are illustrated in figures 6-8, 6-9, 6-10, and 6-11

6.5.3 **b. (1) Early Turn Track and OEA Construction.** Construct a line representing the earliest flight track from the turn side early turn point to the fix. Construct the outer primary and secondary boundary lines of the OEA parallel to this line (1-2-2-1 segment width). From the turn side early turn point, construct a line splaying at 15° from the track until it intersects the parallel boundary lines (see figures 6-8, 6-9, 6-10, and 6-11). Do not apply secondary areas when the 15° splay line intersects the outer primary boundary line at or after the early turn point.

NOTE: If the early track defines a turn greater than 75° from the final approach course, the tieback point of the 15° splay is the corner on the side opposite the turn direction. (E to F). If the early track represents a turn greater than 165° from the final approach course, tieback to the wind spiral start point of the first outside turn wind spiral (see figure 6-7).

6.5.3 **b. (2) Late Turn Track and OEA Construction.** Late turn outer boundary construction applies wind spirals. The following calculations and construction techniques are for wind spiral application. For wind spiral calculations, a bank angle of 15° is used.

Calculate the parameters for the construction of the wind spirals for the appropriate category of aircraft. The wind values are found using formula 2-1b in chapter 2.

6.5.3 **b. (3) Calculation of the No-Wind Turn Radius (R)** is based on formula 6-13.

Formula 6-13
$\mathbf{R} = \dfrac{(\mathbf{V_{KTAS}} + 0)^2 \times (1.4589 \times 10^{-5})}{\tan(15)}$
Example
$V_{KTAS} = 275$
$\mathbf{R} = \dfrac{(275 + 0)^2 \times (1.4589 \times 10^{-5})}{\tan(15)} = 4.12\ \text{NM}$

6.5.3 **b. (4) Calculation of the Turn Rate (TR)** is based on formula 6-14: The maximum TR is 3 deg/sec. If TR >3 deg/sec, use a value of 3 deg/sec.

Formula 6-14

$$\mathbf{TR} = \frac{3431 \times \tan(15)}{\pi \times \mathbf{V_{KTAS}}}$$

Example

$$\mathbf{TR} = \frac{3431 \times \tan(15)}{\pi \times 275} = 1.06 \text{ deg/sec}$$

TR = Turn Rate (Deg/Sec)

6.5.3 **b. (5)** Calculation of wind spiral pitch (Wr). Wr is the increase in radius for each degree of turn (see formula 6-15).

Formula 6-15a

$$\mathbf{Wr} = \frac{\mathbf{V_{KTW}}}{3600\,\mathbf{TR}}$$

where V_{KTW} = wind speed from formula 2-1b

TR = turn rate result of formula 6-14

Example

TR = 1.06 $^{deg}/_{sec}$ Alt = 3100

$$Wr = \frac{53.2}{3600 \times 1.06} = 0.01394$$

6.5.3 **b. (6) Calculation of radius increase (ΔR).** ΔR is the increase in radius for any degree of turn (Φ). Therefore, the radius (R) after Φ degrees of turn is the sum of R and ΔR. See formula 6-15b.

Formula 6-15b

$$\mathbf{\Delta R} = \mathbf{\Phi Wr}$$

where Φ = degrees of turn

Wr = pitch value from formula 6-15a

Example

$\Phi = 67°$ Wr = 0.01394

$$\mathbf{\Delta R} = 67 \times 0.01394 = 0.93$$

If starting R is 4.12, then R at 67°

would be 4.12+0.93=5.05

There are three cases of outer boundary wind spiral construction: Small angle turns requiring one wind spiral (case 1); turns greater than 90° or more requiring a second wind spiral (case 2); and turns exceeding 180° requiring a third wind spiral (case 3). Do not apply secondary areas when the 15° splay line intersects the outer primary boundary line at or after the early turn point. See figure 6-7.

<u>Case 1</u>. Construct a baseline perpendicular to the straight missed approach track at the late turn point. Note that this baseline is beyond the end of the TIA to accommodate bank establishment and a possible tail wind component. Locate the wind spiral center on this baseline at a distance R (no wind turn radius) from the outer boundary of the OEA. Construct the wind spiral from the point on the outer boundary to a point tangent to a line direct to the fix. Construct the outer primary and secondary boundary lines of the OEA parallel to this track (1-2-2-1 segment width). From the wind spiral tangent point, construct a line splaying at 15° from the track until it intersects the parallel boundary lines (see figure 6-8).

Case 2. For turns greater than 90°, a second wind spiral may be necessary. To determine if it is necessary, locate a wind spiral center on the baseline distance R from the inner boundary of the TIA. Construct the wind spiral from the baseline to a point tangent to a line direct to the fix. If the resulting boundary falls outside the construction based on the first wind spiral, the OEA construction must include the second wind spiral (see figure 6-9).

Case 3. For turns of 180° or more (such as a missed approach to a holding fix at the IF), a third wind spiral is constructed at the early turn point on the inner boundary. Examples of these cases are illustrated in figure 6-10. The determination of the need for the second wind spiral (Point B) and the third wind spiral (Point E) may be made by constructing the areas based on the first spiral and checking to see if the area intersects the second wind spiral. If the area does not intersect, the second spiral is not required (see figure 6-5). If the area intersects, the second spiral is required (see figure 6-6). The same procedure is used from the second to the third spiral (see figure 6-7).

Figure 6-8. Fly-By Turn Following Turn at Altitude

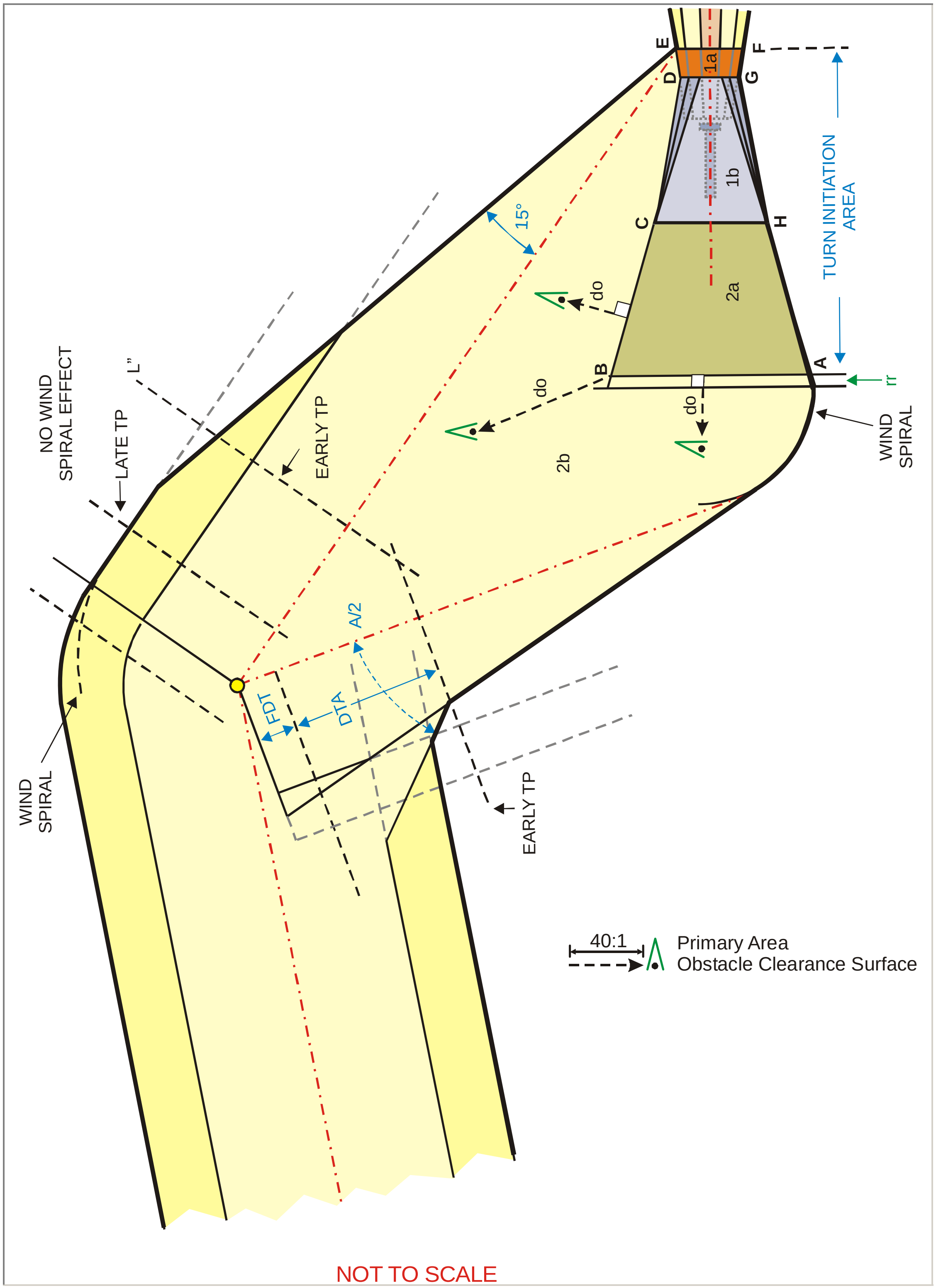
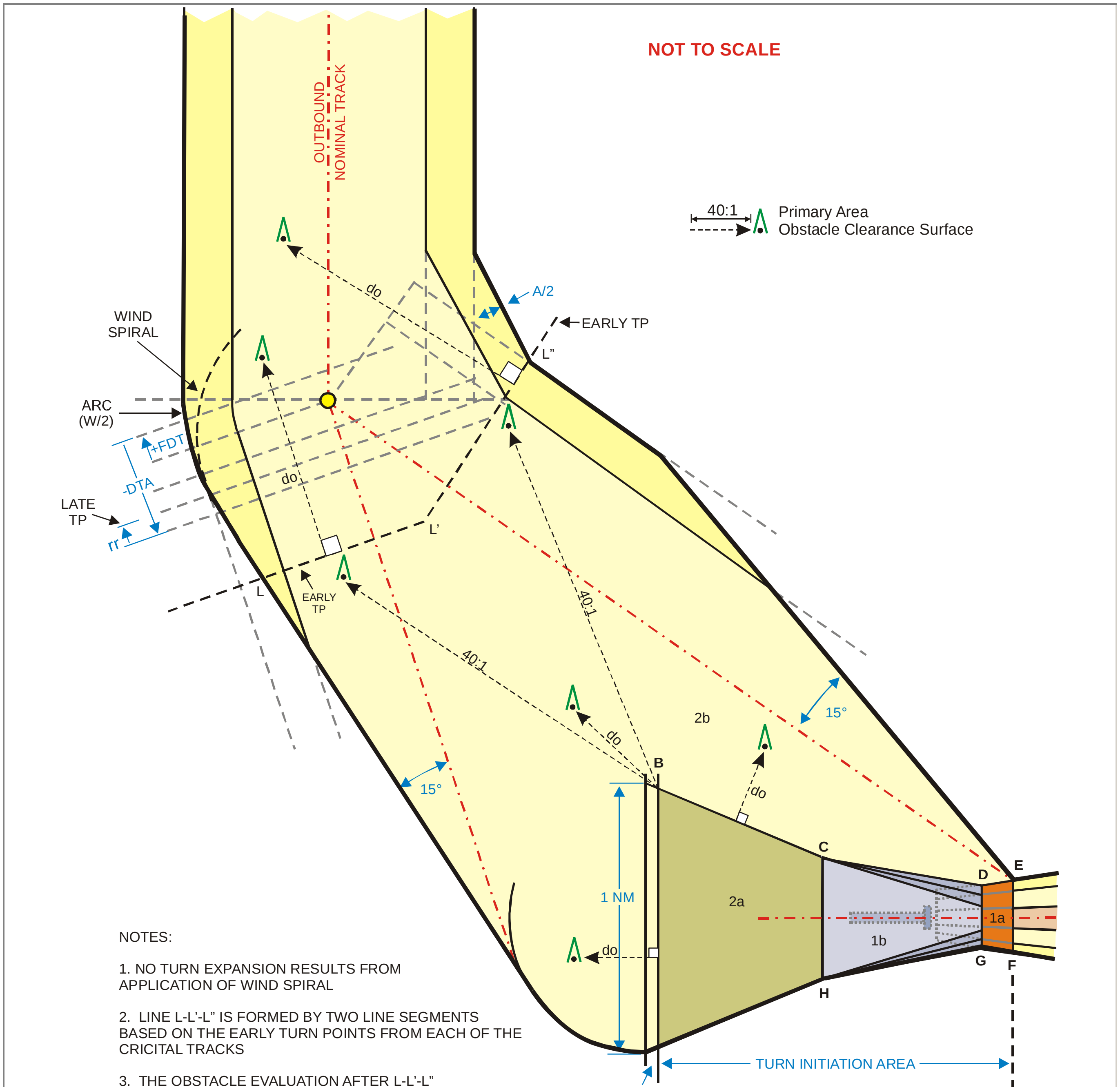


Figure 6-9. Turn at Altitude to Fly-By Waypoint



NOTES:

1. NO TURN EXPANSION RESULTS FROM APPLICATION OF WIND SPIRAL

2. LINE L-L'-L" IS FORMED BY TWO LINE SEGMENTS BASED ON THE EARLY TURN POINTS FROM EACH OF THE CRICITAL TRACKS

3. THE OBSTACLE EVALUATION AFTER L-L'-L" IS BASED ON A CONTINUATION OF THE 40:1 GRADIENT APPLIED OVER THE SHORTEST DISTANCE FROM L-L'-L" TO THE OBSTACLE

4. THE HEIGHT OF LINE L-L'-L" AT ANY POINT IS DETERMINED BY APPLYING THE 40:1 GRADIENT OVER THE SHORTEST DISTANCE FROM THE BOUNDARY OF THE TIA

Figure 6-10. Acute Turn (Fly-By) Following Turn at Altitude

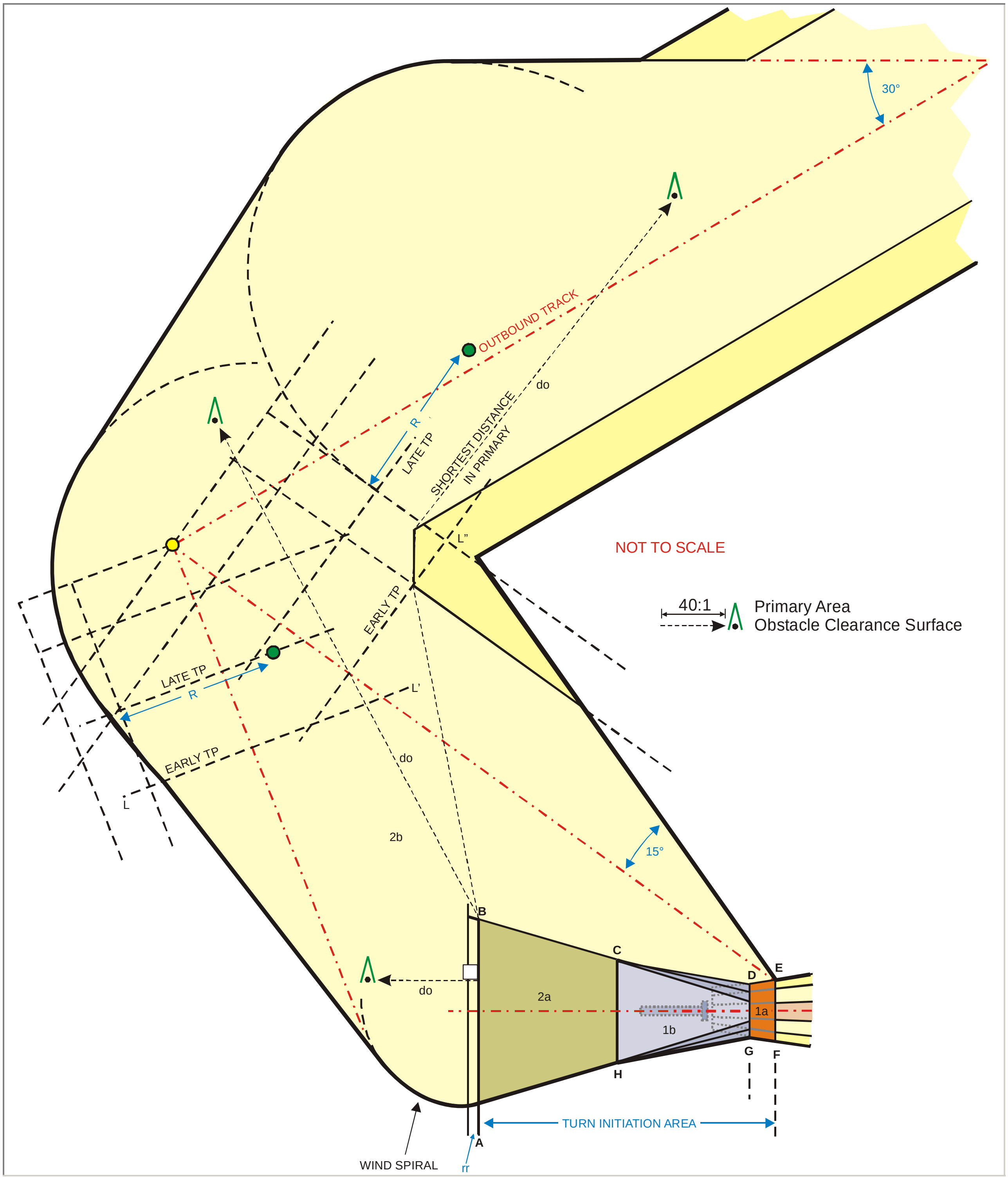
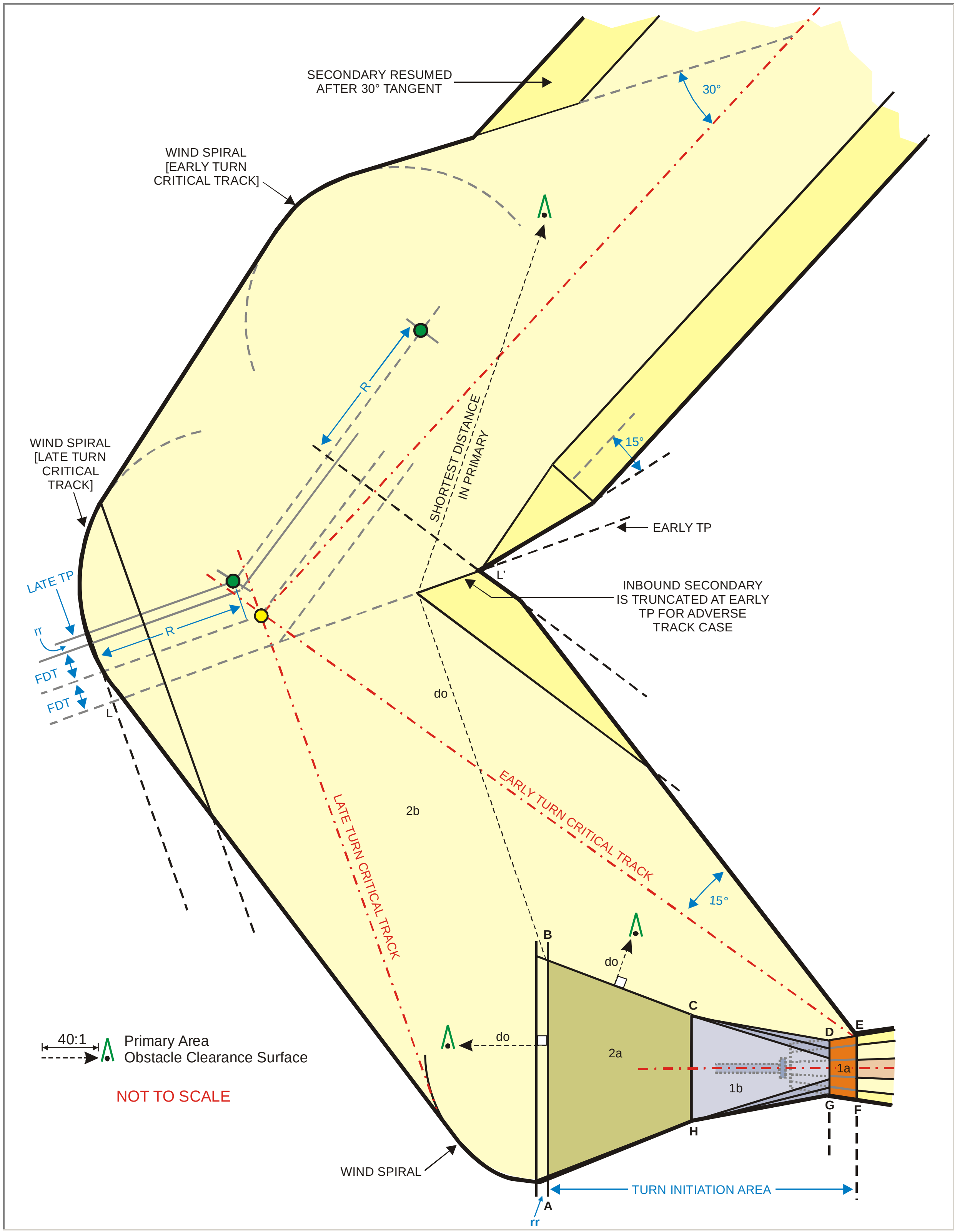


Figure 6-11. Turn at Altitude to a Fly-Over Waypoint



6.5.4 Construction of Turn Area Following the DF Leg.

Turns at the DF path terminator fix will either be fly-by or fly-over to a TF leg. In either case, the outer boundary will provide fly-over protection, and the inner boundary will provide fly-by protection. Fly-by and Fly-over OEAs are constructed using the same principles described above.

6.5.4 **a. Inside Turn Protection.** Locate the early turn point based on the track associated with the inner boundary line. The early turn point is the distance prior to the fix equal to FDT plus DTA. At this point, construct a baseline perpendicular to the inbound track. From the intersection of the baseline and the inner primary and secondary boundaries, construct a line at an angle of one-half the turn angle. This forms the OEA boundary for the early turn protection**.**

6.5.4 **b. Outside Turn Protection.** The construction of the area requires two test spirals to determine the final boundary. The outside turn OEA boundary of the first spiral is based on the late turn point for the track associated with the outside boundary. The second spiral is based on the late turn point for the point associated with the inside boundary. The late turn point is the late FDT.

6.5.4 **b. (1) Locate the late turn point based on the track associated with the outer boundary line.** The late turn point is the distance FDT after the fix. At this point construct a baseline perpendicular to the inbound track. From the intersection of the baseline and the outer primary and secondary boundaries, construct a wind spiral until tangent to a line converging at 30° relative to the outbound track.

6.5.4 **b. (2) Locate the late turn point based on the track associated with the inner boundary line.** The late turn point is the distance FDT after the fix. At this point construct a baseline perpendicular to the inbound track. From the intersection of the baseline and the inner primary and secondary boundaries, construct a wind spiral until tangent to a line converging at 30° relative to the outbound track.

6.5.4 **b. (3) Compare the outer boundary** of the area enclosed by the wind spirals to the outer boundary of the area associated with the outbound track. If the larger area results from the wind spiral construction, form the outer boundary by the wind spirals and a tangent line converging 30° relative to the outbound track. Do not apply secondary areas until after the 30° line intersects the outer boundary associated with the outbound track. If the wind spirals do not form a larger area, the outer boundary is constructed with arcs of radius 2 NM for the primary and 3 NM for the secondary. The intersection of the 30° line with the outbound track identifies the earliest allowable position for the early turn point of a subsequent fix.

6.5.5 Turns at a Fix.

The missed approach can be constructed with the initial turn at a fix. This fix can be fly-by or fly-over. Fly-over fixes should be used **only** where fly-by does not provide obstacle avoidance or where mandatory for specific operational requirements. The earliest turn point for the turn fix must be located at or beyond the end of section 1B.

6.5.5 **a. TIA.** The TIA for turns at fixes extends from the early turn point to the latest turn point. The early turn point for fly-by fixes is at a distance of FDT plus DTA prior to the fix. The early turn point for fly-over fixes is the early FDT. The late turn point for fly-by fixes is located at a position relative to the fix determined by a distance of DTA prior to the late FDT. The late turn for fly-over fixes is a distance of FDT plus rr beyond the turn fix.

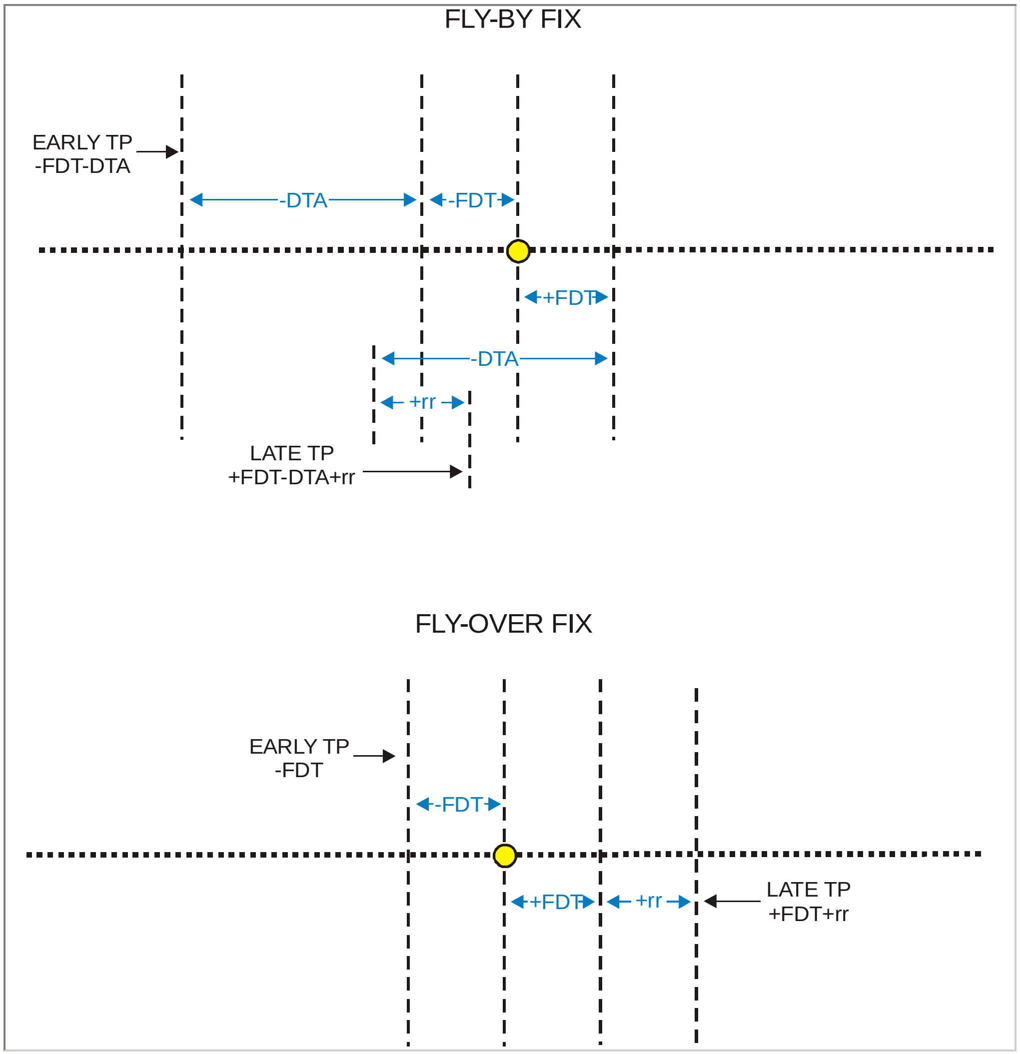
Fly-by fixes (see figure 6-12).

$$\mathbf{Early\,TP} = \mathbf{Fix} - \mathbf{FDT} - \mathbf{DTA}$$
$$\mathbf{Late\,TP} = \mathbf{Fix} + \mathbf{FDT} - \mathbf{DTA} + \mathbf{rr}$$

Fly-over fixes (see figure 6-12).

$$\mathbf{Early\,TP} = \mathbf{Fix} - \mathbf{FDT}$$
$$\mathbf{Late\,TP} = \mathbf{Fix} + \mathbf{FDT} + \mathbf{rr}$$

Figure 6-12. Diagram of Fly-Over/Fly-By Fix



6.5.5 **b. Early Turn Protection.** The early turn point is protected by splaying the area at 15° from the outbound track until reaching the boundaries of the outbound segment.

6.5.5 **c. Late Turn Protection.** Protection is provided from the latest turn point by wind spirals that are joined to the boundaries of the outbound segment or by fixed radius boundaries when wind spirals do not result in OEA expansion.

6.5.6 **Turns at a Fix Construction.**

The maximum turn is 90°. The first turn fix must be located on the final approach track extended.

6.5.6 **a. Fly-By Turn Calculations and Construction.** The following guidance considers a distance in the opposite direction of flight to be negative, while a distance in the direction of flight to be positive.

6.5.6 **a. (1) Calculate the distance ($D_{earlyTP}$)** from the fix to the early turn point using formula 6-16:

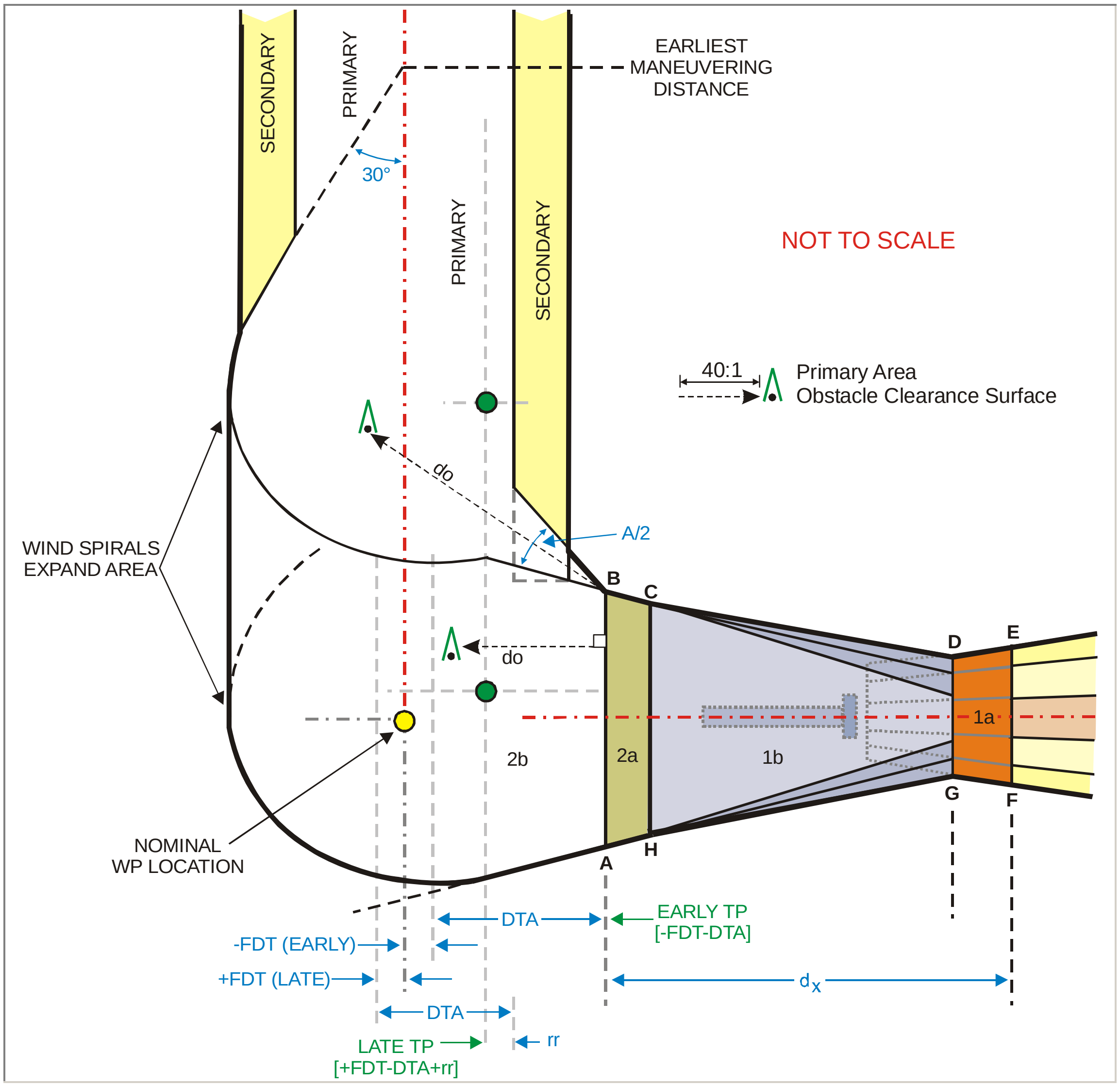
Formula 6-16
$D_{earlyTP} = FDT + DTA$
Example
FDT = 0.3 NM DTA = 1.25
$D_{earlyTP} = 0.3 + 1.25 = 1.55$ NM

6.5.6 **b. Area Construction for the Early Turn.**

6.5.6 **b. (1) Inside turn construction.** The method of inside turn expansion construction is dependent upon the location of the early turn point baseline.

If the baseline falls outside the boundary of the outbound segment, construct the turn expansion area with lines from the points where the early turn baseline intersects the primary and secondary boundaries of the inbound segment at an angle of one-half the turn angle to join the boundaries of the outbound segment (see figure 6-13).

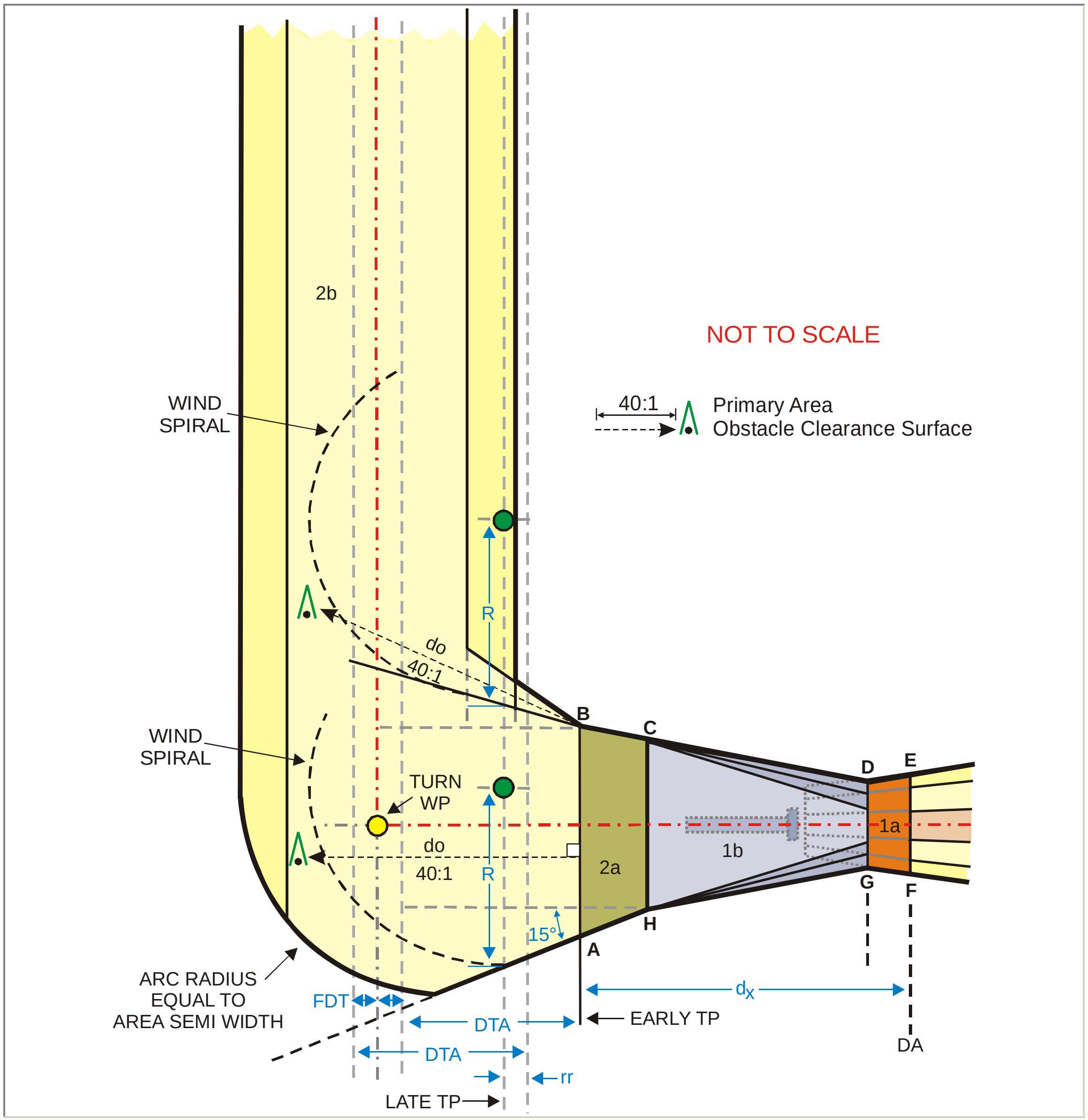
Figure 6-13. Turn at Waypoint Fly-By



If the baseline falls inside the boundary of the outbound segment, construct the turn expansion area with a line from the point where early turn baseline intersects the inbound segment boundary splaying at 15° relative to the outbound track until intersecting the boundary of the outbound segment. For turn angles greater than 75°, the origin of the 15° splay is the outer boundary of the inbound segment at the early turn point (see figure 6-14).

Apply secondary areas after the turn expansion lines intersect the outbound segment boundaries.

Figure 6-14. Turn at Waypoint Fly-By

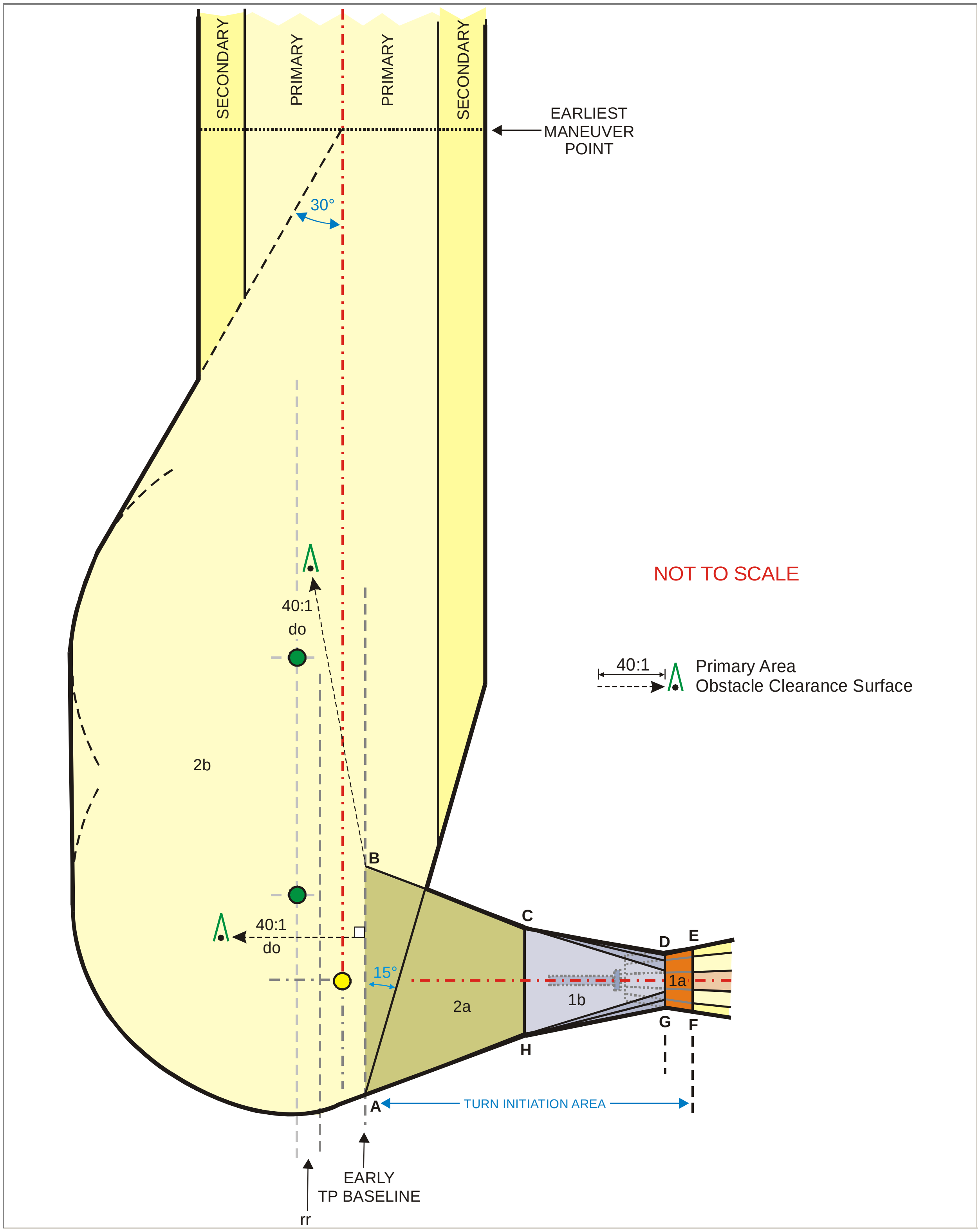


Calculate the distance (**D**$\mathbf{D_{lateTP}}$) from the fix to the late turn point using formula 6-17. A positive result is a position following the fix, a negative result is a position prior to the fix.

Formula 6-17
$D_{lateTP} = FDT - DTA + rr$
Example
where FDT = 1.0 DTA = 1.25 rr = 0.24
$D_{lateTP} = 1.0 - 1.25 + 0.24 = -0.01$

6.5.6 **c. Area Construction for the Late Turn Point.** Apply the wind spiral to the outer boundaries at the late turn point until tangent to a line converging 30° relative to the outbound track. The wind spiral application follows the method described for turns at altitude. The intersection of the 30° line with the outbound track identifies the earliest allowable position for the early turn point of a subsequent fix. This construction is illustrated in figure 6-15.

Figure 6-15. Turn at Waypoint Fly-Over 90°



6.5.6 **c. (1) Obstacle evaluation after the turn** is based on a 40:1 OCS applied beginning at the early turn point line at the height of the OCS for the inbound segment, and continuing as the shortest distance from the early turn line to the obstacle. See figures 6-9, 6-13, 6-14, and 6-15 for examples of obstacle measurement.

6.5.6 **d. Fly-Over Turn Construction.**

6.5.6 **d. (1) Area Construction.** From the inner boundary of the inbound segment, at the early turn point, construct a line splaying 15° from the outbound track until intersecting the outer boundary of the outbound segment area. For turn angles greater than 75°, the origin of the 15° splay is the outer boundary of the inbound segment at the early turn point. Apply secondary areas after the turn expansion lines intersect the outbound segment boundaries (see figure 6-14).

6.5.7 Area Construction.

6.5.7 **a. Construct the wind spiral** from the outer boundary, continuing until converging to the outbound track at 30°. Apply a second wind spiral if required. Construct the outer boundary using the 30° line tangent from the latest wind spiral. Apply secondary areas after the 30° line (see figure 6-15).

6.5.7 **b. Obstacle Evaluation after the Turn**. Obstacles after the turn are based on a 40:1 OCS beginning at the early turn line at the height of the 40:1 for the inbound segment. The OCS is applied over the shortest distance from the early turn line to the obstacle. This is illustrated in figure 6-15.

6.5.7 **c. The point where the 30° tangent line** intersects the outbound track identifies the earliest maneuvering point associated with the next fix.

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